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# FINAL REPORT

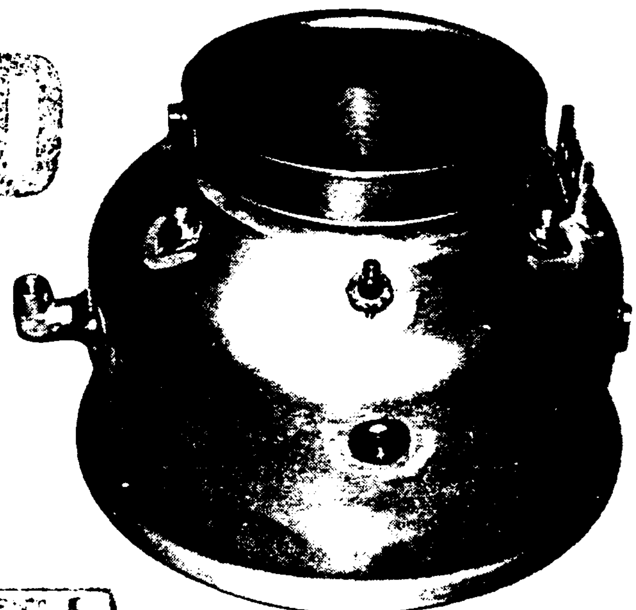
## INDUSTRIAL MODERNIZATION INCENTIVE PROGRAM (IMIP)

PHASE II

SEPTEMBER, 1989 - MARCH, 1991

## *SUNDSTRAND'S PRECISION METAL FORMING CELL*







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SUNDSTRAND POWER SYSTEMS WAS SUCCESSFULL IN UTALIZING AND DEVELOPING ~~AND~~ ADVANCED MANUFACTURING MACHINE TOOLS AND TECHNIQUES IN FABRICATING COMBUSTOR HOUSING ASSEMBLYS. TECHNOLOGYS DEVELOPED WERE: FLOW FORMING AND LASER MACHINING AND WELDING. SIGNIFICANT REDUCTIONS IN COST AND LEADTIME, WITH INCREASED CONTROLL ON QUALITY.

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# FINAL REPORT

**IMIP PHASE II**

***PRECISION METAL FORMING CELL***

**CONTRACT F41608-89-C-1458**
**SEPTEMBER, 1989 - MARCH 1991**



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# 1.0 SUMMARY AND CONCLUSIONS

## 1.1 BACKGROUND

At this time all sheet metal component details from Sundstrand Power Systems (SPS) are purchased from outside vendor sources. In this present situation product costs are high, quality issues are difficult to resolve, and the ability to meet delivery schedules is at the mercy of many different suppliers. In addition, the combustor assembly housings have sustained in-field fatigue failures caused by high loading under high temperature conditions.

A Precision Metal Forming Cell became the subject of an Industrial Modernization Incentives Program (IMIP) funded by the Department of the Air Force. The Phase I study funded under contract F41608-86-C-0746, was completed in October, 1987. Initial studies in Phase I indicated that the combustor housing could be fabricated as a one-piece design, using Hastelloy X material, thereby producing a stronger and more reliable product. Further, the Phase I study indicated that the use of flow forming could produce the one-piece des.gn at a significant savings.

The IMIP Phase II study, funded under contract F41608-89-C-1458, was complete by March 31, 1991. The Phase II study under the direction of Rich Barbier, reference Section 2.0 (Phase II Management Plan), is complete and this report provides the results of the Phase II study.

## 1.2 OBJECTIVES

The objectives of the IMIP Phase II study were to:

1. Perform engineering analyses necessary to evaluate the new one-piece design and material selection, reference Section 3.0.

2. Evaluate, test, and develop flow forming technology in support of combustor housing fabrication, reference Section 4.0.

3. Evaluate, test, and develop laser welding and machining technology in support of combustor housing fabrication and assembly, reference Section 5.0.

4. Develop an Implementation Plan for the Precision Metal Forming Cell, reference Section 6.0.

5. Confirm and update the Cost/Benefit Analysis of implementing the new facility, reference Section 7.0.

## 1.3 RESULTS

The IMIP Phase II study has verified that the one-piece combustor housing design fabricated from Hastelloy X material using flow forming and deep draw operations will produce a stronger more durable unit to that which is currently being used.

The use of laser cutting and welding to fabricate the combustor housing assembly does not have any adverse effects on the Hastelloy X material.

The implementation of a Precision Metal Forming Cell at Sundstrand, in San Diego, will show a cost savings for the combustor housing assembly on military programs of $5,167,200 over a five year period once Sundstrand starts fabrication of production units. This equates to an Investment Return Rate (IRR) to the D.O.D. of 12.8% on projected contract with SPS thru 1995.

REFERENCE APPENDIX "C" DISCOUNTED CASH FLOW MODEL

## 1.4 RECOMMENDATIONS AND CONCLUSIONS

Sundstrand recommends that all combustor housing assemblies be produced using the new one-piece design using flow forming and laser technology.

Sundstrand plans to implement the new Precision Metal Forming Cell, reference Section 6.0.

Any cost risk associated with the implementation of the new facility is minimal due to the conservative approach taken by Sundstrand in the Cost/Benefit Analysis, reference Section 8.0.

# 2.0 PHASE II MANAGEMENT PLAN

## 2.1 PROGRAM MANAGEMENT

Sundstrand Power Systems (SPS) utilized Program Office concepts to structure and coordinate the diverse activities that were performed as part of its IMIP project, and to manage the resources required to perform those activities. This included management of both internal (SPS) resources and any outside (subcontractor) resources which were utilized to assist SPS in this effort.

### 2..1.1 Program Management Organization

SPS established a management organization for the execution of the IMIP Phase II project. It is composed of a Project Management Review Board, a Program Manager, and a Project Engineer as shown in Figure 2-1.

#### 2..1.1.1 IMIP Management Review Board

The Management Review Board is composed of the General Manager, Directors from Finance, Operations, Engineering, and Quality Assurance. They participated in periodic reviews of the IMIP project to ensure the contractual, financial, and technological goals of SPS and the Air Force Logistics Command were met. The Management Review Board was assisted by the Technical Review Board, as required.

#### 2.1.1.2 IMIP Program Manager

Bob Goddard was selected to continue the IMIP Phase II project as Program Manager. Mr. Goddard had overall responsibility for the project and reported directly to the IMIP Management Review Board.

#### 2.1.1.3 IMIP Project Engineer

Rich Barbier was selected as the IMIP Phase II Project Engineer. Reporting directly to the Program Manager, Mr. Barbier was responsible for the planning and coordination of the personnel resources required for the project; supervising field work; obtaining time, expense, and progress reports from the IMIP project team members; and preparing periodic project management reports for the IMIP Review Board and the government. The Project Engineer was also responsible for reviewing all project deliverables; reviewing work at the completion of each task; developing and maintaining the detailed Program Master Plan and Schedule; maintaining communications with appropriate management to ensure a sufficient understanding of current project matters; coordinating and managing the efforts of all subcontractors; and identifying important issues or problems and resolving them promptly.

## 2.2 IMIP TEAM

The IMIP Project Team were key personnel selected to report to the Project Engineer and to be responsible to the Project Engineer as a focal point for all IMIP related activities within their area of responsibility, reference Figure 2-2.

## 2.3 PROGRAM STATUS SURVEILLANCE

Based on the program personnel (as identified above) and the technical approach, a program plan and schedule were developed along with a Work Breakdown Structure (WBS) to control and monitor the status of the project throughout planned effort. Figure 2-3 shows the Summary Project Schedule. Figures 2-4 and 2-4A show the WBS and the hours used within each area. Note that the hours shown in Figure 2-4 reflect the hours through March 10, 1991.

# INDUSTRIAL MODERNIZATION INCENTIVES PROGRAM

## *Organization Plan*

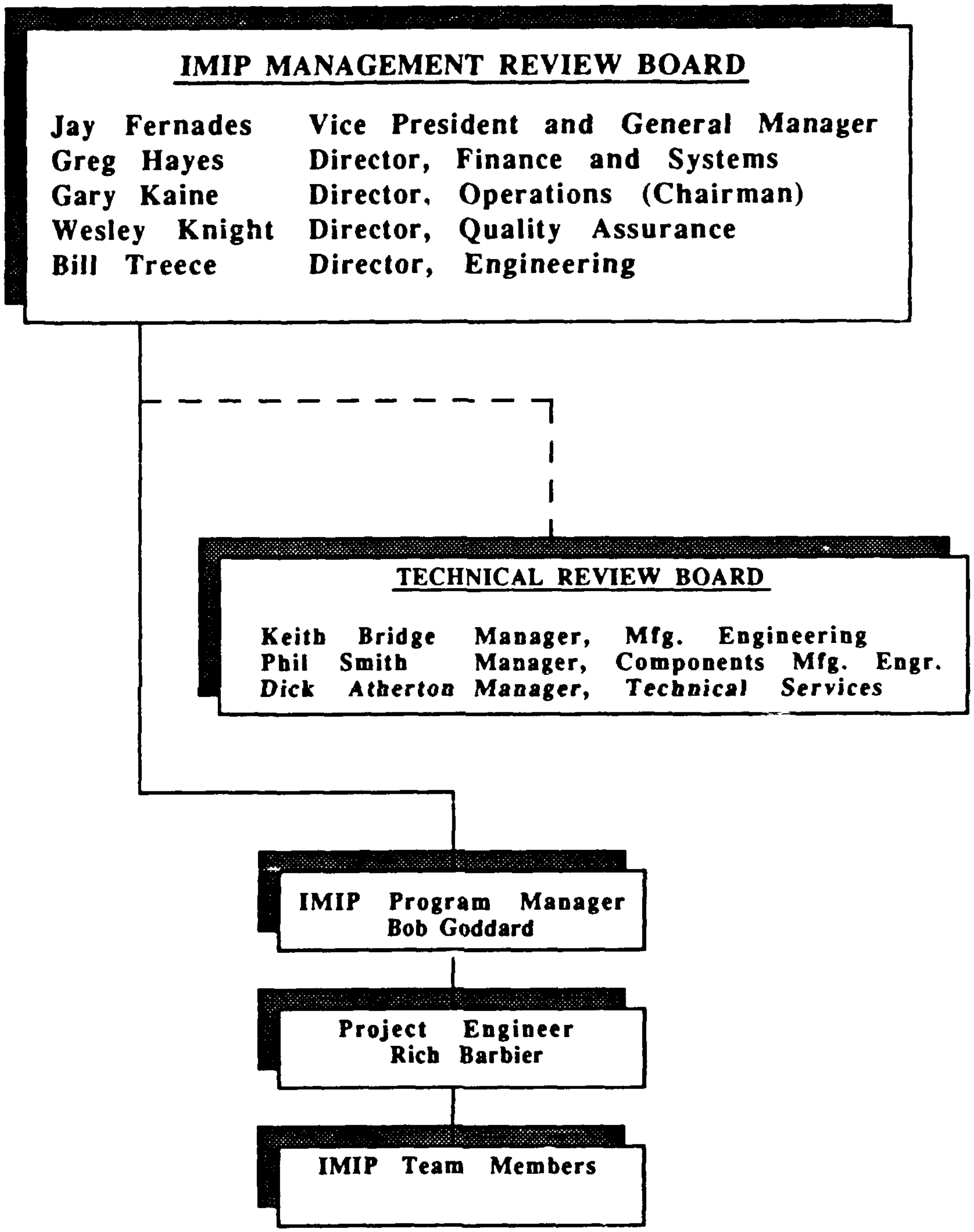



Figure 2-1 Program Management Organization

## IMIP TEAM

***Program Team***

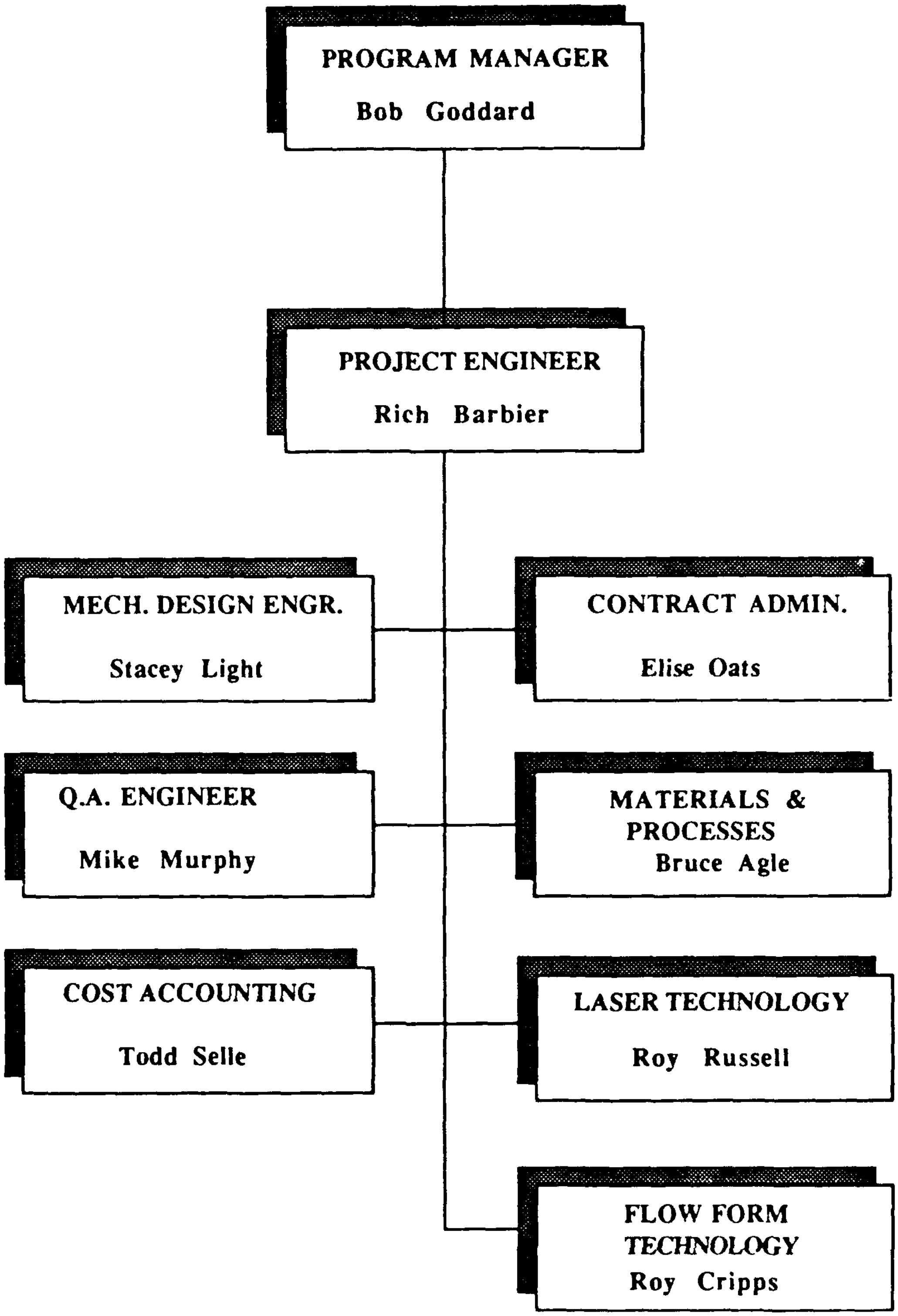



Figure 2-2 IMIP Project Team

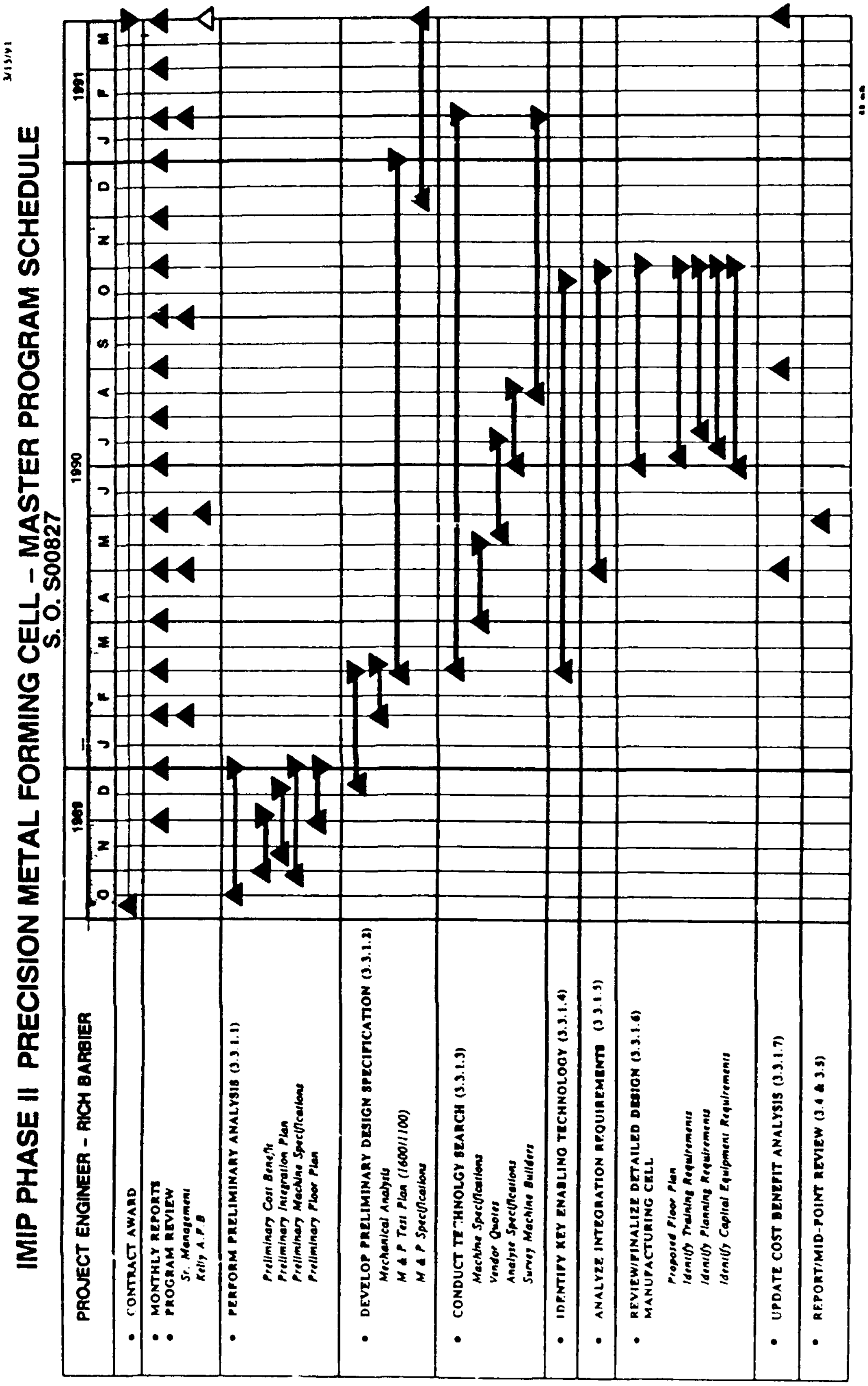



Figure 2-3A IMIP Phase II Master Program Schedule

3/15/91

# IMIP PHASE II PRECISION METAL FORMING CELL - MASTER PROGRAM SCHEDULE

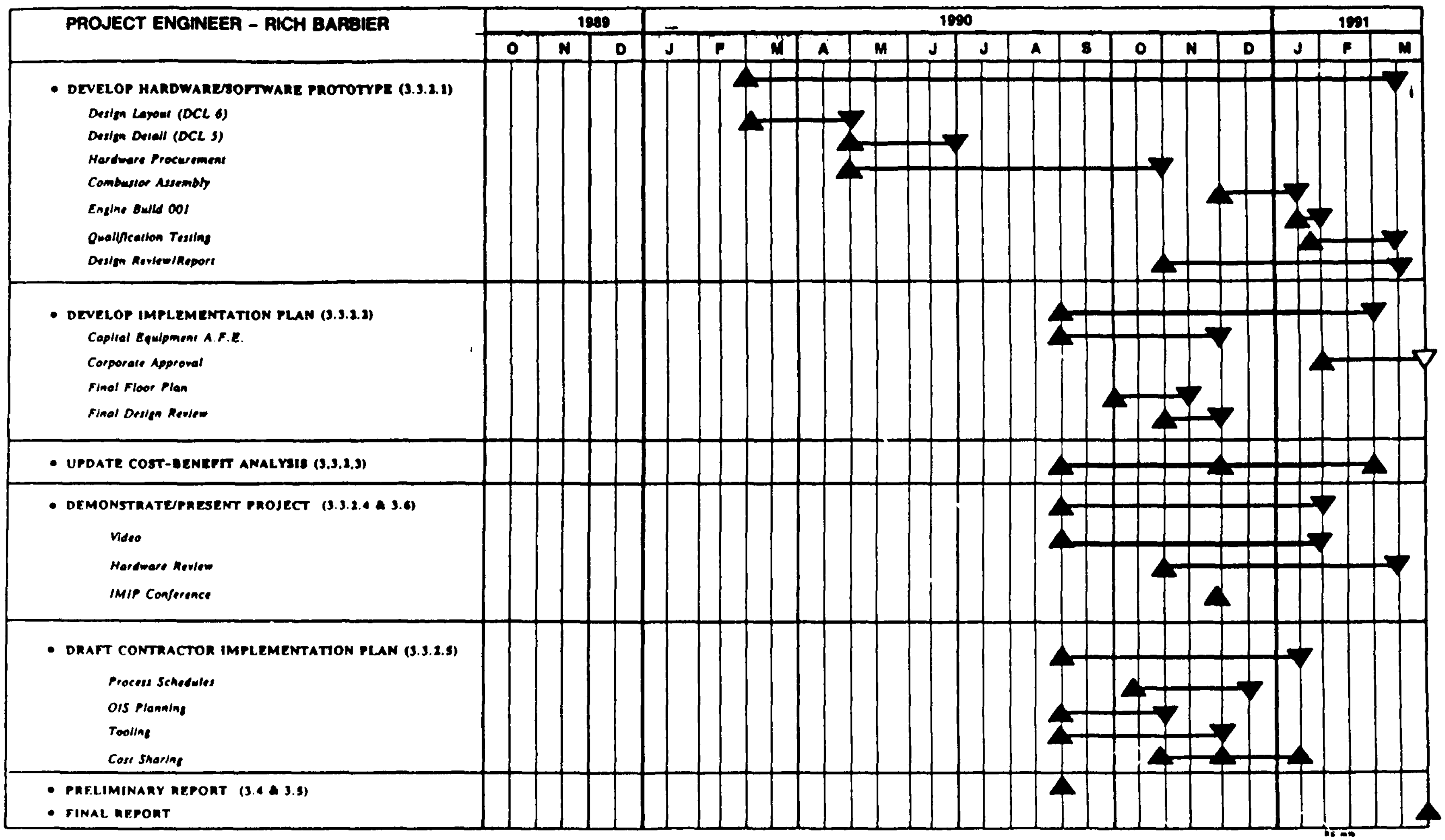



Figure 2-3B IMIP Phase II Master Program Schedule

# Work Breakdown Structure

**S00827**
**IMIP Phase II A**

### Months 1 & 2
*11/89 & 12/89*

| Task | | Subtask |
|---|---|---|
| 1100 | 600/387 | 1110 |
| Perform Preliminary System Analysis | | |

| Res | | Hrs |
|---|---|---|
| 1641 | M&P | 60 |
| 1654 | Combustion | 50 |
| 1691 | Project | 50 |
| 1717 | Q E | 20 |
| 1450 | Comp M E | 320 |
| 1450 | Weld M E | 80 |
| 1700 | Prog Mgt | 60 |

| Task | | Subtask |
|---|---|---|
| 4000 | 7511000 | 1111 |
| Design | | |

| Res | | Hrs |
|---|---|---|
| 1623 | Mech Design | 32 |

### Months 3 & 4
*1/90 & 2/90*

| Task | | Subtask |
|---|---|---|
| 1100 | 600/388 | 1120 |
| Develop Preliminary Design Specs. | | |

| Res | | Hrs |
|---|---|---|
| 1641 | M&P | 60 |
| 1654 | Combustion | 65 |
| 1691 | Project | 50 |
| 2978 | Travel | $7181 |
| 1450 | Comp M E | 320 |
| 1450 | Weld M E | 120 |
| 1700 | Prog Mgt | 60 |

| Task | | Subtask |
|---|---|---|
| 4000 | 7511001 | 1121 |
| Design | | |

| Res | | Hrs |
|---|---|---|
| 1623 | Mech Design | 40 |

### Months 4 & 5
*2/90 & 3/90*

| Task | | Subtask |
|---|---|---|
| 1100 | 600/389 | 1130 |
| Conduct Technology Search | | |

| Res | | Hrs |
|---|---|---|
| 2978 | Travel | $1394 |
| 1450 | Comp. M.E. | 160 |
| 1450 | Weld M.E. | 239 |
| 1691 | Project | 25 |
| 1700 | Prog Mgt | 30 |
| O/H | Purchasing | 18 |
| O/H | P Q A. | 122 |

### Month 6
*4/90*

| Task | | Subtask |
|---|---|---|
| 1100 | 600/390 | 1140 |
| Identify Key Fundamental Technology | | |

| Res | | Hrs |
|---|---|---|
| 1717 | Q E | 15 |
| 1450 | Weld M E | 80 |
| 1450 | Comp M E | 75 |
| 1700 | Prog. Mgt | 30 |
| 1691 | Project | 25 |

### Month 7
*5/90*

| Task | | Subtask |
|---|---|---|
| 1100 | 600/391 | 1150 |
| Analyze Integration Requirements | | |

| Res | | Hrs |
|---|---|---|
| 1641 | M&P | 40 |
| 1717 | Q E | 25 |
| 1450 | Weld M E | 160 |
| 1450 | Comp M E | 160 |
| 1700 | Prog Mgt | 30 |
| 1691 | Project | 25 |

### Months 7 & 8
*5/90 & 6/90*

| Task | | Subtask |
|---|---|---|
| 1100 | 600/392 | 1160 |
| Review/Finalize Design Configuration | | |

| Res | | Hrs |
|---|---|---|
| 1700 | Prog Mgt | 60 |
| 1450 | Comp M E | 80 |
| 1450 | Weld M E | 40 |
| 1611 | Aerothermal | 20 |
| 1621 | Stress | 5 |
| 1622 | Heat Transfer | 40 |
| 1717 | Q E | 10 |
| 1641 | M&P | 40 |
| 1691 | Project | 25 |

| Task | | Subtask |
|---|---|---|
| 4000 | 7511002 | 1161 |
| Design | | |

| Res | | Hrs |
|---|---|---|
| 1623 | Mech Design | 36 |
| 1675 | Drafting | 110 |
| 1674 | Checker | 30 |

### Month 8

| Task | | Subtask |
|---|---|---|
| 1100 | 600/393 | 1170 |
| Update Cost Benefit Analysis | | |

| Res | | Hrs |
|---|---|---|
| 1450 | Comp M E | 20 |

CR6341
10/24/89

Figure 2-4 IMIP Phase II WBS

# Work Breakdown Structure

**S00827**
**IMIP Phase II B**

*Months 8, 9, 10 & 11*
*6/90, 7/90, 8/90 & 9/90*

| Task | | Subtask |
|---|---|---|
| 1200 | 600/534 | 1210 |

Develop
Hardware Prototype

| Res | | Hrs |
|---|---|---|
| 1450 | Weld M E | 400 |
| 1450 | Comp M E | 580 |
| 1425 | Dev Assy | 33 |
| 1700 | Prog Mgr | 120 |
| 1453 | Inspection | 80 |
| 1611 | Aerothermal | 25 |
| 1631 | Dev Test Engr | 350 |
| 1632 | Dev Test Mech | 450 |
| 1633 | Dev Test Elect | 160 |
| 1641 | M&P | 80 |
| 1642 | M&P Tech | 80 |
| 1654 | Combustion | 90 |
| 1621 | Stress | 10 |
| 1691 | Project | 75 |
| 2978 | Travel | $18,802 |
| 1717 | Q E | 40 |
| 2902 | Fuel | $12,250 |
| 2918 | Avr Mat'l | $18,400 |
| 2998 | Tooling | $87,500 |

| Task | | Subtask |
|---|---|---|
| 4000 | 751/003 | 1211 |

Design

| Res | | Hrs |
|---|---|---|
| 1623 | Mech Design | 32 |
| 1675 | Drafting | 10 |
| 1675 | Checking | 10 |

*Months 12 & 13*
*10/90 & 11/90*

| Task | | Subtask |
|---|---|---|
| 1200 | 600/335 | 1220 |

Develop
Implementation Plan

| Res | | Hrs |
|---|---|---|
| 1450 | Comp M E | 160 |
| 1450 | Weld M E | 100 |
| 1450 | Industrial E | 160 |
| 1700 | Prog Mgr | 60 |
| 1691 | Project | 50 |
| 1717 | Q E. | 40 |

*Months 12, 13, 14*
*10/90, 11/90 & 12/90*

| Task | | Subtask |
|---|---|---|
| 1200 | 600/538 | 1250 |

Draft Implementation
Proposal

| Res | | Hrs |
|---|---|---|
| 1700 | Prog Mgr | 120 |
| 1450 | Comp M E | 60 |
| O/H | Cost Acctg | 120 |

*Month 13*
*11/90*

| Task | | Subtask |
|---|---|---|
| 1200 | 600/396 | 1230 |

Update Cost
Benefit Analysis

| Res | | Hrs |
|---|---|---|
| 1450 | Comp M E | 30 |

*Months 13 & 14*
*11/90 & 12/90*

| Task | | Subtask |
|---|---|---|
| 1400 | 600/400 | 1110 |

Project
Deliverables

| Res | | Hrs |
|---|---|---|
| 1450 | Comp M E | 340 |
| 1700 | Prog Mgr | 40 |
| 2918 | Purch Mat'l | $13,000 |
| O/H | Cost Acctg | 180 |

*Month 13*
*11/90*

| Task | | Subtask |
|---|---|---|
| 1500 | 600/401 | 1110 |

Project Savings
Validation

| Res | | Hrs |
|---|---|---|
| 1450 | Comp M E | 80 |
| 1700 | Proj Mgr | 40 |
| O/H | Cost Acctg | 320 |

*Month 14*
*12/90*

| Task | | Subtask |
|---|---|---|
| 1200 | 600/597 | 1240 |

Demonstrate
Present Project

| Res | | Hrs |
|---|---|---|
| 1621 | Stress | 3 |
| 1717 | Q E | 30 |
| 1450 | Weld M E | 40 |
| 1450 | Comp M E | 160 |
| 1700 | Prog Mgr | 30 |
| 1691 | Project | 25 |

| Task | | Subtask |
|---|---|---|
| 1200 | 751/004 | 1241 |

DESIGN

| Res | | Hrs |
|---|---|---|
| 1623 | Mech Design | 20 |

*Months 6 & 14*
*4/90 & 12/90*

| Task | | Subtask |
|---|---|---|
| 1300 | 600/555 | 1110 |

Program Management

| Res | | Hrs |
|---|---|---|
| 1700 | Prog Mgr | 120 |
| 1278 | Travel | $3212 |

Figure 2-4A IMIP Phase II WBS

# 3.0 DESIGN

## 3.1 PROBLEM

The T-62T-40 style combustor housing currently in service in the KC-135 and JFS APU's is subject to early cracking and or non-repairable distortion due to high cycle fatigue, especially in the KC-135 application. Therefore, it was necessary to design a housing that gives a marked increase in structural integrity, without compromising weight and/or cost.

## 3.2 DESIGN CONCEPT

The existing design is shown in Figure 3-1, the new design is shown in Figure 3-2.

### 3.2.1 OUTER CASE

The new design incorporates a one-piece outer case with integral V-band flange at the housing inlet. The thicknesses are in general .028-.036 along the outer diameter and .040-.048 in the dome region.

### 3.2.2 DIFFUSER

The new diffuser is also a one-piece design at a thickness of .038-.046 with an integral V-band flange at one end.

### 3.2.3 BOSSES, ETC.

All of the bosses, except for the igniter, have been designed to eliminate separate sheet metal doublers and incorporate integral soleplate doublers per the latest Sundstrand design criteria. The bosses on the O.D. of the case are made from bar stock designed to be produced from a numerical control lathe operation. The 6 fuel manifold bosses have been changed to machine investment castings so that they conform to the conical dome shape. The igniter boss still maintains a sheet metal doubler so that the height of the boss from the start nozzle can be set at assembly.

### 3.2.4 JOINT DESIGN

All joints are designed for brazing, although laser welding was developed under the IMIP Program as a means of reducing cost and increasing durability of the housing assembly, see Section 4.0.

## 3.3 ANALYSIS

There were three engineering analyses completed in support of the new design: TRR-0892 (Stress Analysis), TRR-0919 (Thermal Analysis), and TRR-0935 (Dimensional Analysis).

### 3.3.1 STRESS ANALYSIS (TRR-0892)

To achieve the required increase in structural integrity, two outer combustor housing materials were considered, SS 321 and Hastelloy X (the current inner diffuser wall material). The final combustor housing configuration was selected

based on both pressure and thermal effects (reference TRR-0919 and TRR-00935). Pressure loading determined the final configuration, but thermal effects established material choice, based on component stress levels and life cycle fatigue requirements.

3.3.1.1 CONFIGURATION SELECTION

To investigate the relative merits between the proposed combustor housing configurations, 3D Finite Element (FE) models were created. Each FE model consisted of a 45 degree sector, with the following boundary and load conditions, refer to Figure 3-3 for model idealization.

Boundary Conditions:

(a) The combustor housing outer flange was constrained in the axial direction only, allowing the housing to move radially.

(b) Symmetrical boundary constraints were applied to the sector.

(c) The inner diffuser wall was constrained radially at the nozzle interface to prevent the diffuser wall from distorting unrealistically.

Load Conditions:

(a) Maximum pressure load condition taken from the KC-135 cycle desk, Cold Day (-40 degrees F) Sea Level = 90 psia for 75.3 psig.

3.3.1.2 RESULTS

The maximum equivalent stress levels for the proposed new combustor housing configurations, based on pressure loading only are given in Table I, together with the current design. Figures 3-4, 3-5, and 3-6 indicate the location of the maximum equivalent stress for the conical, vertical, and current dome configurations, respectively. A vertical dome design in SS 321 is not given in Table I, due to the increase in wall thickness required to reduce the stress levels below the current configuration level. Based on Table I results, the conical dome combustor housing was chosen.

3.3.1.3 MATERIAL SELECTION

To investigate material selection, the combined effects of pressure and temperature at various engine conditions were applied to the final combustor configuration, reference Table II.

Applied Load Conditions:

(a) Standard Day, Sea Level
T amb = 59 degrees F; EGT = 1300 degrees F
Pressure = 57.0 psig

(b) Hot Day, Sea Level
T amb = 130 degrees F; EGT = 1300 degrees F
Pressure = 48.4 psig

(c) Cold Day, Sea Level
T amb = -40 degrees F; EGT = 1300 degrees F
Pressure = 75.3 psig

3.3.1.4 RESULTS

Figures 3-7, 3-8, and 3-9 represent the equivalent, bending and hoop stress for the conical dome configuration with a SS 321 outer casing, for the Standard Day load condition. Figure 3-10 represents the thermal distribution applied to the FE model for this condition.

Figures 3-11 thru 3-21 represent the equivalent stresses for an all Hastelloy X combustor housing assembly.

3.3.2 THERMAL ANALYSIS (TRR-0919)

The thermal analysis of the KC 135 combustor housing has been completed using the ANSYS model created for the stress analysis. Three conditions were analyzed:

(a) T amb = 59 degrees F; EGT = 1300 degrees F (Standard Day)

(b) T amb = 130 degrees F; EGT = 1300 degrees F (Hot Day)

(c) T amb = -40 degrees F; EGT = 1300 degrees F (Cold Day)

3.3.2.1 RESULTS

Figure 3-22 shows the results of the analysis for the 59 degree day condition. The outer casing is running slightly above compressor discharge temperature at the outer diameter. The maximum temperature of the outer casing is 1095 degrees at the braze joint with the diffuser. The diffuser temperature varies from 852 to 1300 degrees F. Also shown in Figure 3-22 are the combustor liner temperatures obtained from thermal paint results and the compressor discharge air temperature distribution. Figures 3-23 and 3-24 show the temperatures for the 130°F and -40°F conditions, respectively.

## 3.4 CONCLUSIONS

3.4.1 An all Hastelloy X combustor assembly is best because it reduces the high stress levels produced by the large variation in thermal expansion rates between Hastelloy X and Stainless Steel 321. Maximum stress levels for the all Hastelloy X combustor are below the minimum yield strength of the material and therefore, permanent deformation of the casing will not be an issue. A summary of stress levels for an all Hastelloy X assembly is shown in Table III.

3.4.2 A change to an all Hastelloy X combustor housing will standardize present combustor designs.

3.4.3 The new combustor housing exceeds the component pressure test requirement of twice maximum pressure at twice the operating temperature without rupture, as required in MIL-P-85573, paragraph 4.5.4.1.

3.4.4 The inner diffuser wall of 0.04 inches in Hastelloy X prevents bucking of the diffuser cone under all applied load conditions.

3.4.5 Life cycle fatigue life for the combustor has been calucated to exceed 50,000 cycles even with a stress concentration factor of 3.

3.4.6 High Cycle Fatigue (HCF) is dependent on the alternating stress level produced by an external forcing function acting on the housing. If the magnitude of the forcing function is unknown, HCF life cannot be accurately evaluated. However, based on KC-135 in-service results, combustor outer casings with a minimum material thickness of .025 inches (in the dome region) have not shown signs of HCF failure. Therefore, the new combustor configuration with a dome thickness of .040 inches will increase component life significantly.

* F.S. = Factor of Safety

* F.S. = Factor of Safety

*   *   *   *

**TableI**

**Combustor Housing Maximum Equivalent Stress**
**Pressure Load only**

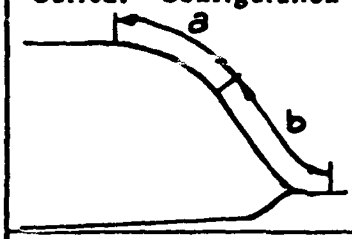
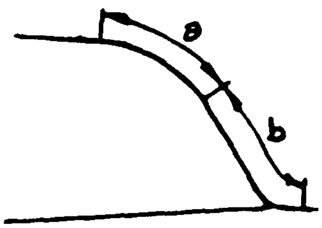
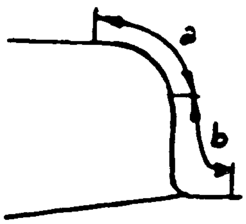
| Combustor Configu'ation | Mazimum Thicknes Inches | Minimum Weight Pounds | Maximum Applied Pressure | Maximum Stress psi |
|---|---|---|---|---|
| Current Configuration  | a = .023 - .023<br>b = .023 - .023 | 4.11 | 75.3 | 36,500 |
| Concial  | a = .028 - .040<br>b = .040 - .040 | 4.91 | 75.3 | 17,775 |
| Vertical  | a = .023 - .080<br>b = .080 - .080 | 6.20 | 75.3 | 37,500 |

**Table II**

**Standard Day Stress Levels - Outer Casing**

* Factor of Safety

| Stress Component | Max. Stress (psi) | Temp. (°F) | Minimum Yield (psi) | Minimum Ultimate (psi) | * F.S Yield | * F.S Ultimate |
|---|---|---|---|---|---|---|
| Equivalent | 43,002 | 1060 | 18,000 | 46,000 | 0.42 | 1.07 |
| Bending | -46,683 | 1060 | 18,000 | 46,000 | 0.39 | 0.99 |
| Hoop | -45,067 | 1060 | 18,000 | 46,000 | 0.40 | 1.02 |

Table III

All Hastelloy X Combustor Stress Simmary

* Factor of Safety

| Load Condition | Temp. °F | Max. Stress Levels (psi) | | | Min. Yield (psi) | Min. Ultimate (psi) | * F.S Yield (Equiv) | * F.S Ultimate (Equiv) |
|---|---|---|---|---|---|---|---|---|
| | | Equivalent | Bending | Hoop | | | | |
| Standard Day | 773 | 18571 | 9588 | 18009 | 37,800 | 91,350 | 2.04 | 4.92 |
| Hot Day | 909 | 16306 | 9127 | 15665 | 37,350 | 88,200 | 2.29 | 5.41 |
| Cold Day | 709 | 22997 | 9292 | 22727 | 38,700 | 94,500 | 1.68 | 4.11 |

**PARTS LIST**

| | |
|---|---|
| 167180-1 | Manifold Bracket |
| 163241-1 | Exhaust Flange |
| 163211-1 | Drain Elbow |
| 162910-3 | Outer Case |
| 162909-1 | Exhaust Diffuser |
| 162908-2 | Igniter Doubler |
| 162907-1 | Drain Boss Doubler |
| 162906-1 | Tube Ftg. Doubler (6) |
| 162905-1 | Forward Flange |
| 100645-1 | Tube Ftg. (6) |
| 100643-1 | Inj. Nut Disc |
| 100642-1 | Pin Nut Disc (4) |
| 49265-1 | Ign. Plug Boss |
| 24003-0 | Fitting (2) |
| 163737-2 | Hex Nut Pin (4) |
| 163737-4 | Inj. Nut |

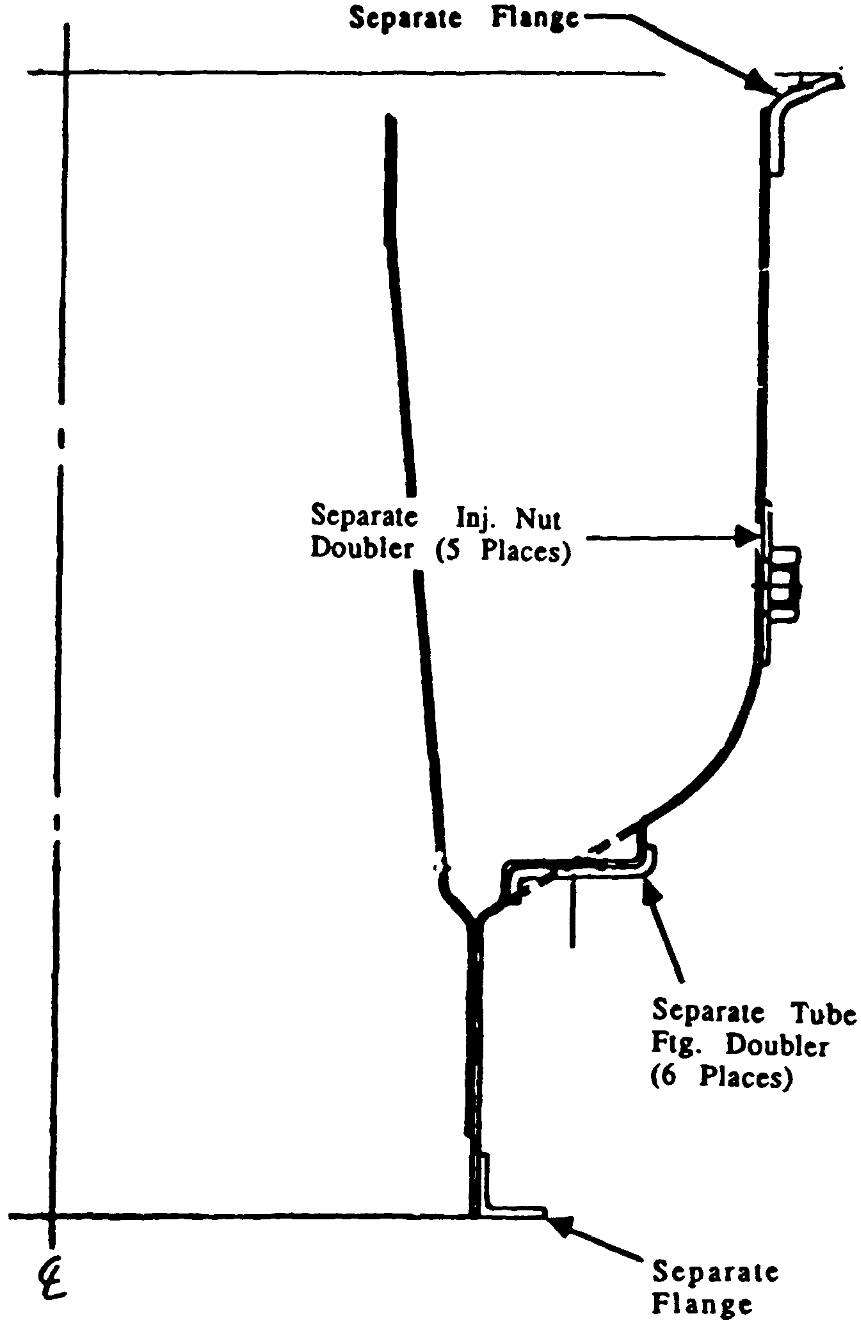



Figure 3-1 Existing Combustor Design

**PARTS LIST**

| | | |
|---|---|---|
| 167180-1 | Manifold Bracket | Same |
| 163211-1 | Drain Elbow | Same |
| 162910-3 | Outer Case | Flow Formed |
| 162909-1 | Exhaust Diffuser | Flow Formed |
| 162908-2 | Igniter Doubler | Modified |
| 162907-1 | Drain Boss Doubler | Modified |
| 100645-1 | Tube Ftg. (6) | Modified |
| 49265-1 | Ign. Plug Boss | Same |
| 24003-0 | Fitting (2) | Modified |
| 163737-2 | Hex Nut Pin (4) | Modified |
| 163737-4 | Inj. Nut | Modified |

**PARTS REMOVED**

| | | |
|---|---|---|
| 163241-1 | Exhaust Flange | Part of Diffuser |
| 162906-1 | Tube Ftg. Doubler (6) | Part of Case |
| 162905-1 | Forward Flange | Part of Case |
| 100643-1 | Inj. Nut Disc. | Part of Case |
| 100642-1 | Pin Nut Disc. (4) | Part of case |

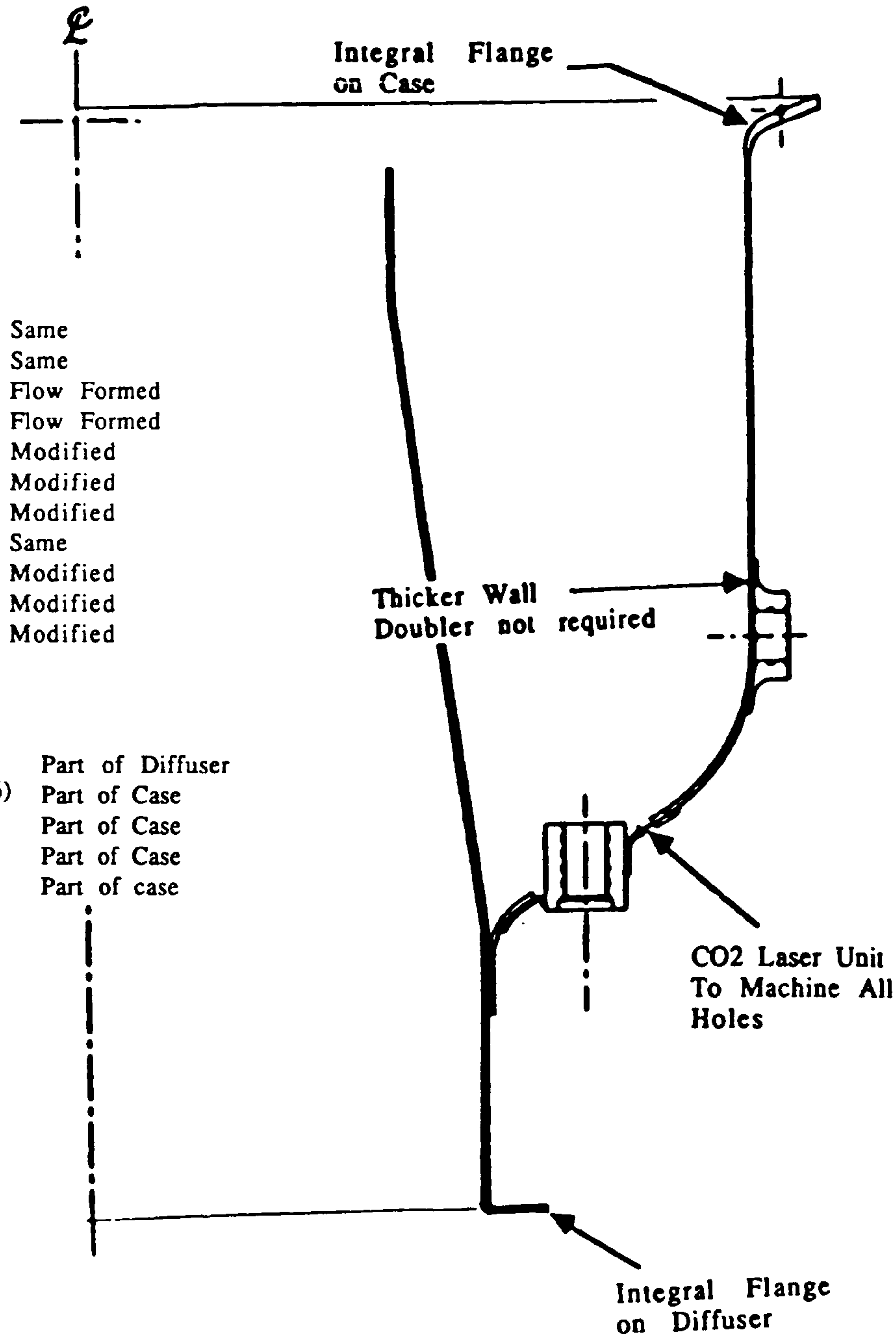



Figure 3-2 New Combustor Design

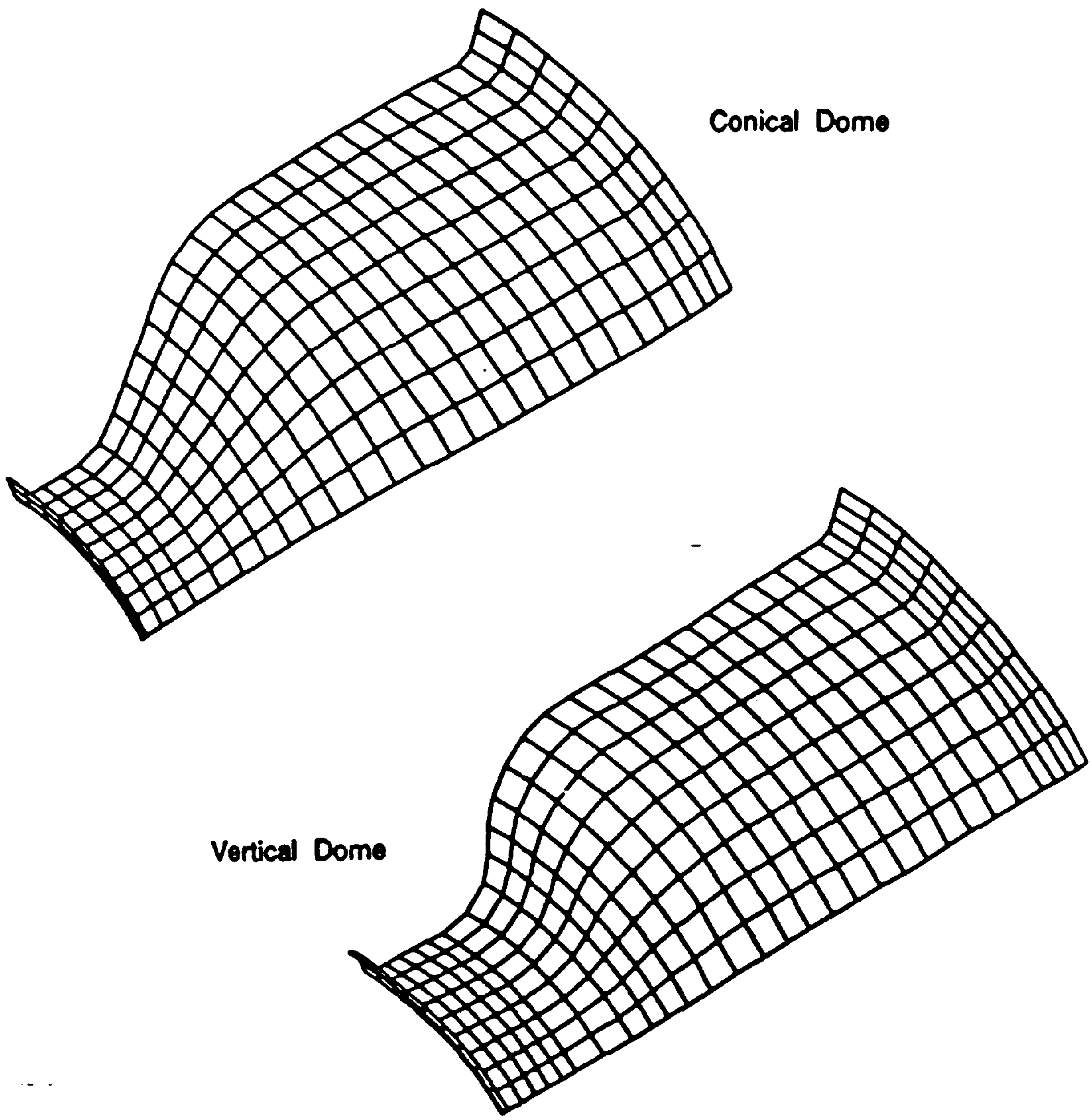



Figure 3-3 F.E. Model Idealization (a) Concial Dome (b) Vertical Dome

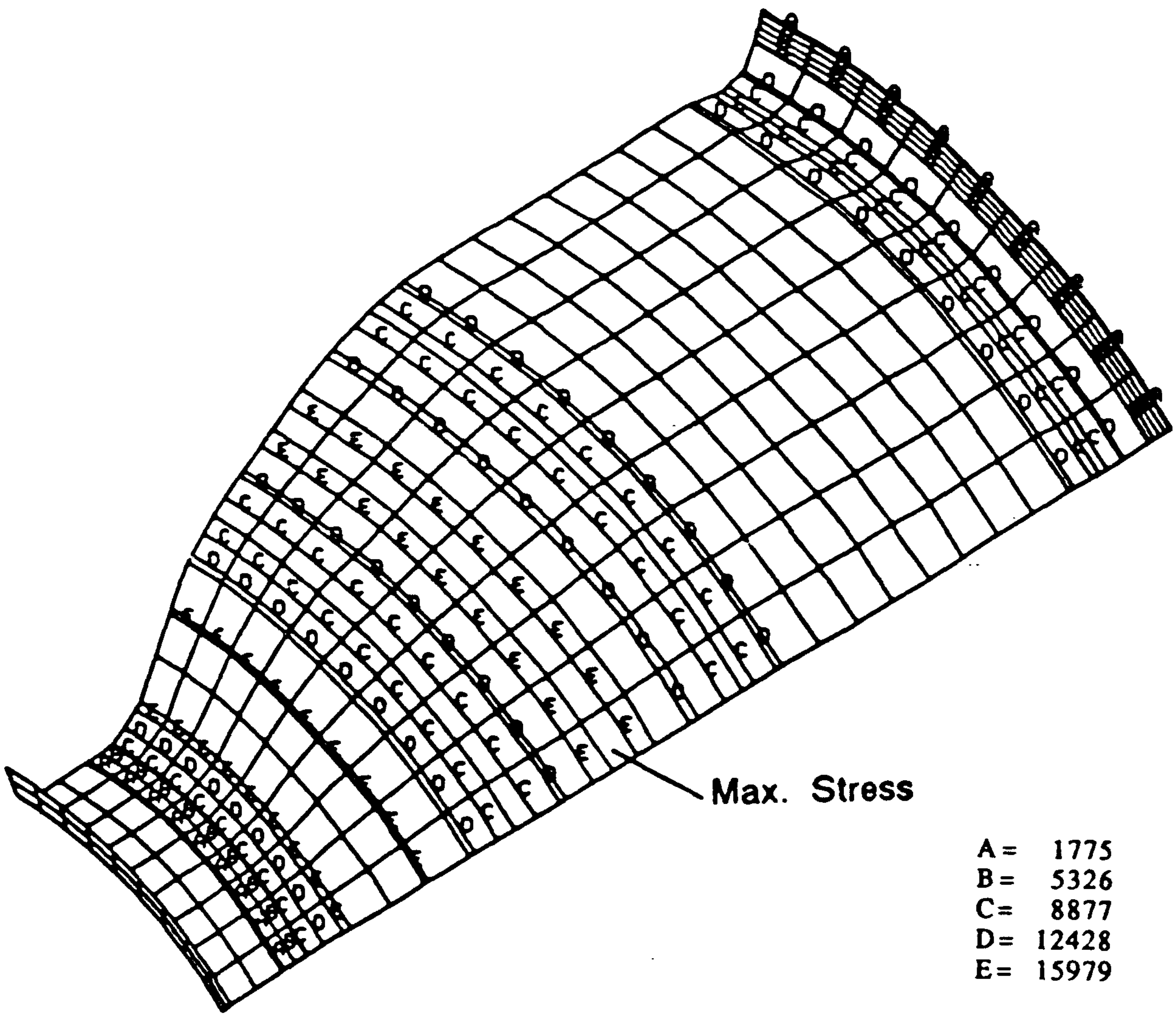



Figure 3-4 Maximum Equivalent Stress - Concial Dome - Pressure Load Only

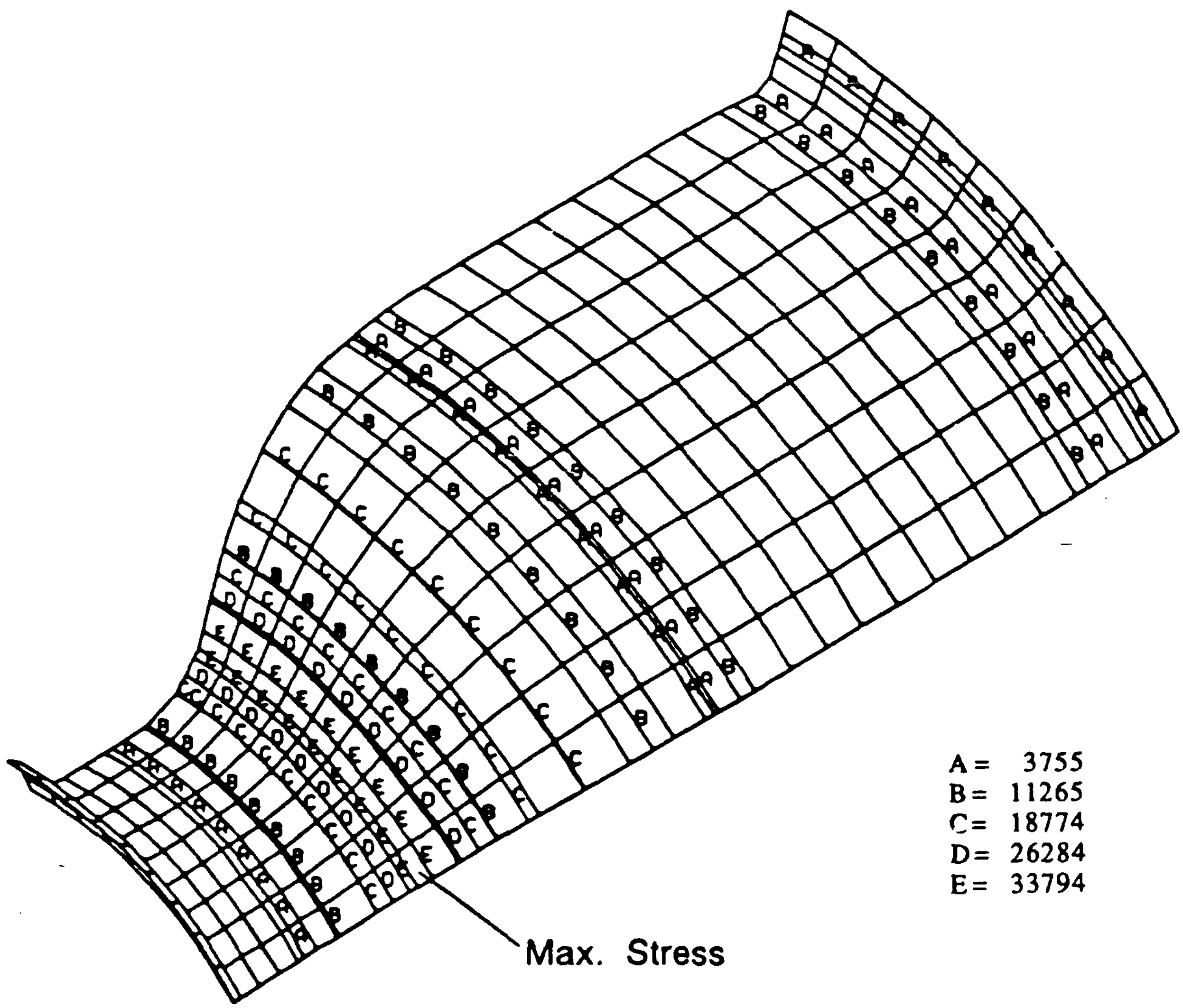



Figure 3-5 Maximum Equivalent Stress - Vertical Dome - Pressure Load Only

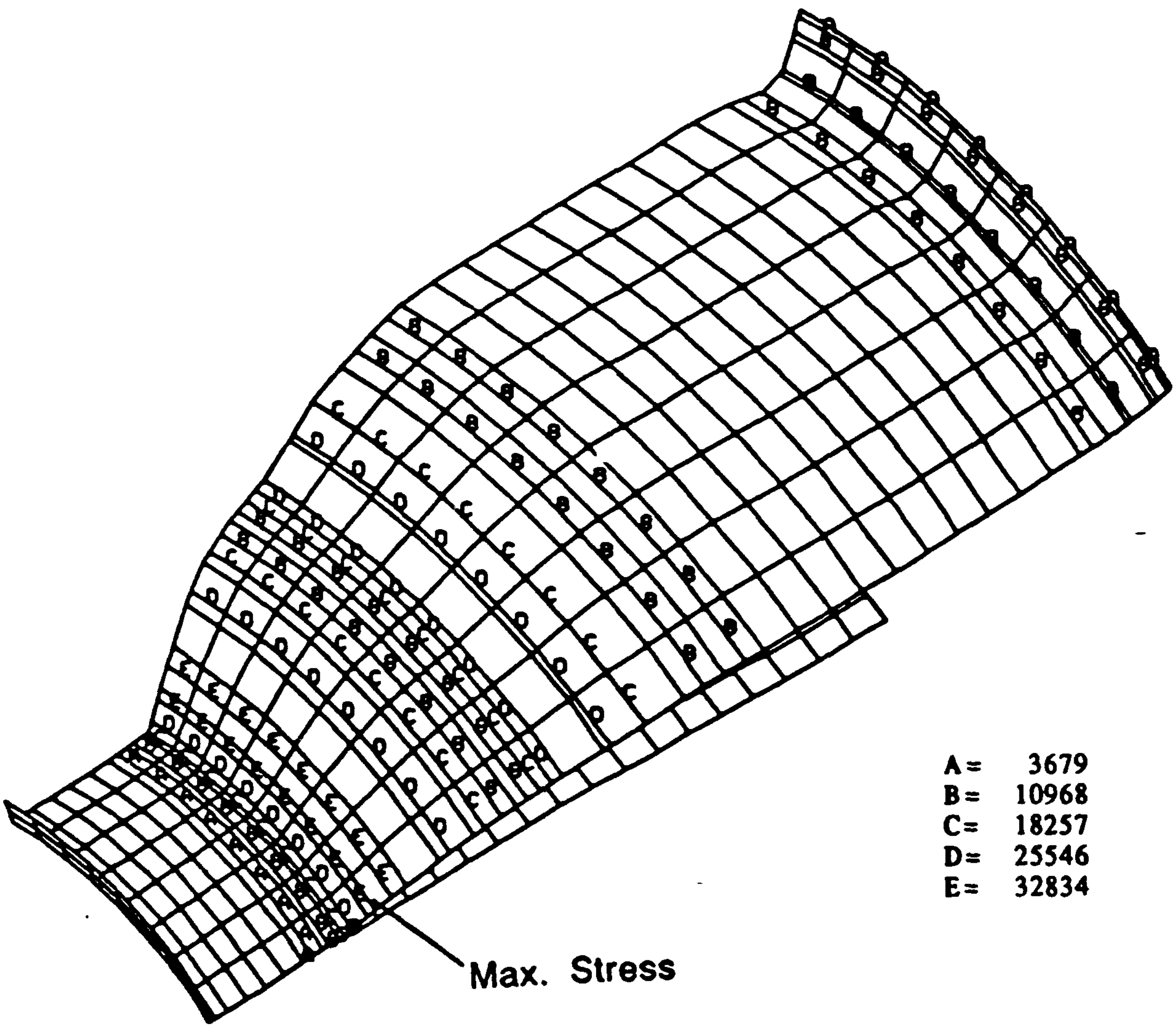



Figure 3-6 Maximum Equivalent Stress - Current Configuration
Pressure Load Only

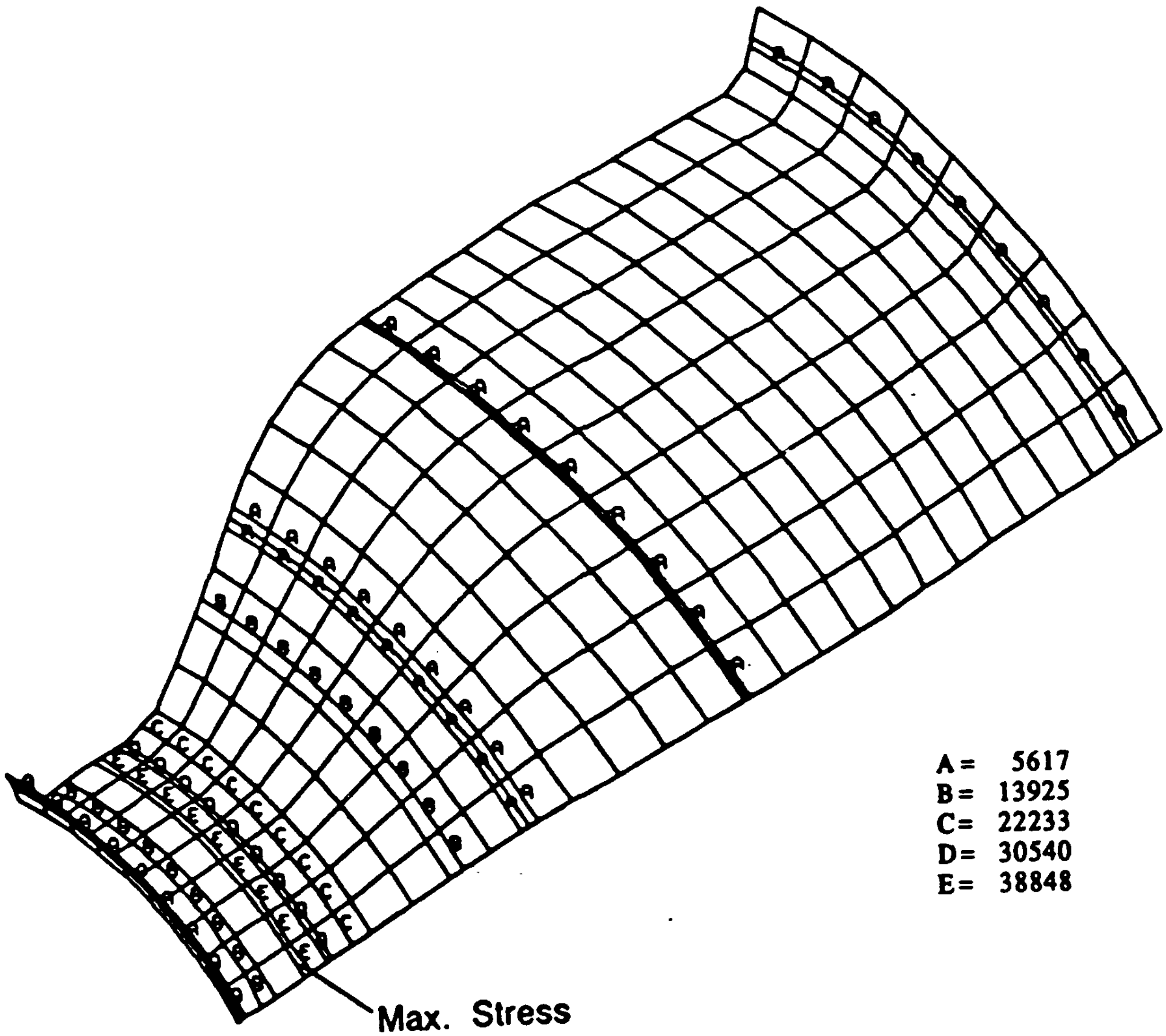



Figure 3-7 Maximum Equivalent Stress - Standard Day Load
Concial Dome in SS 321

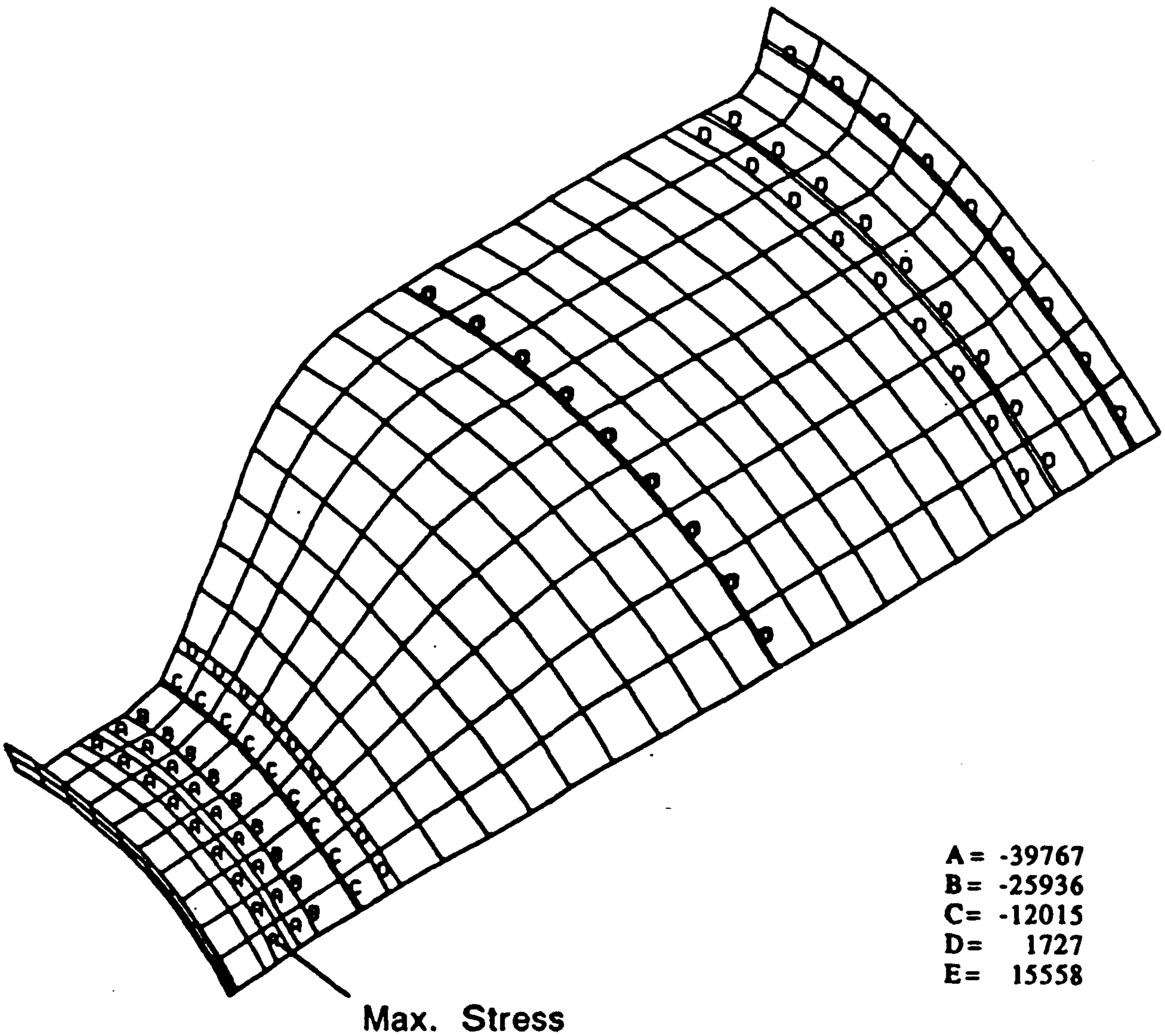



Figure 3-8 Maximum Bending Stress - Standard Day Load
Concial Dome in SS 321

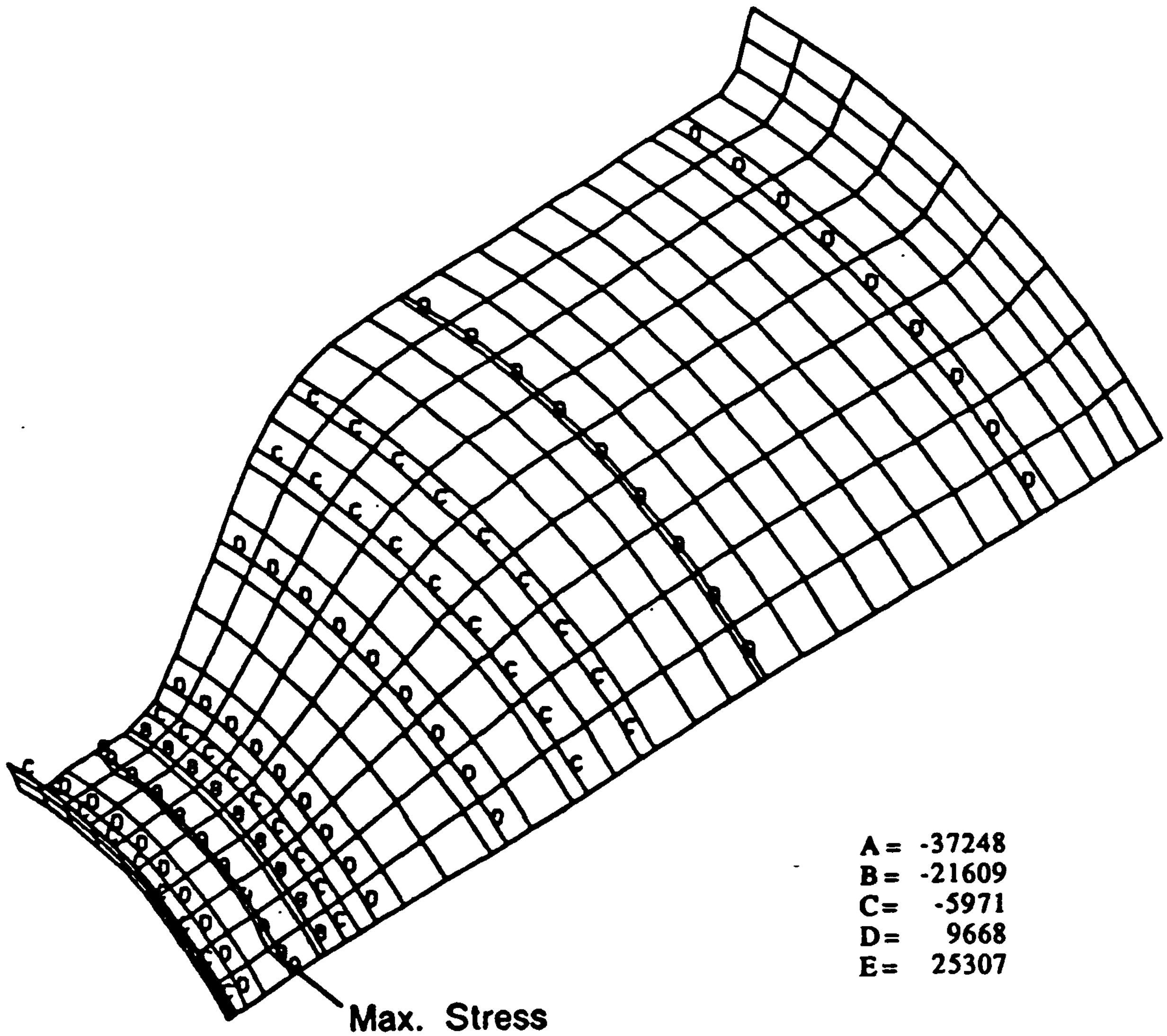



Figure 3-9 Maximum Hoop Stress - Standard Day Load Condition
Concial Dome in SS 321

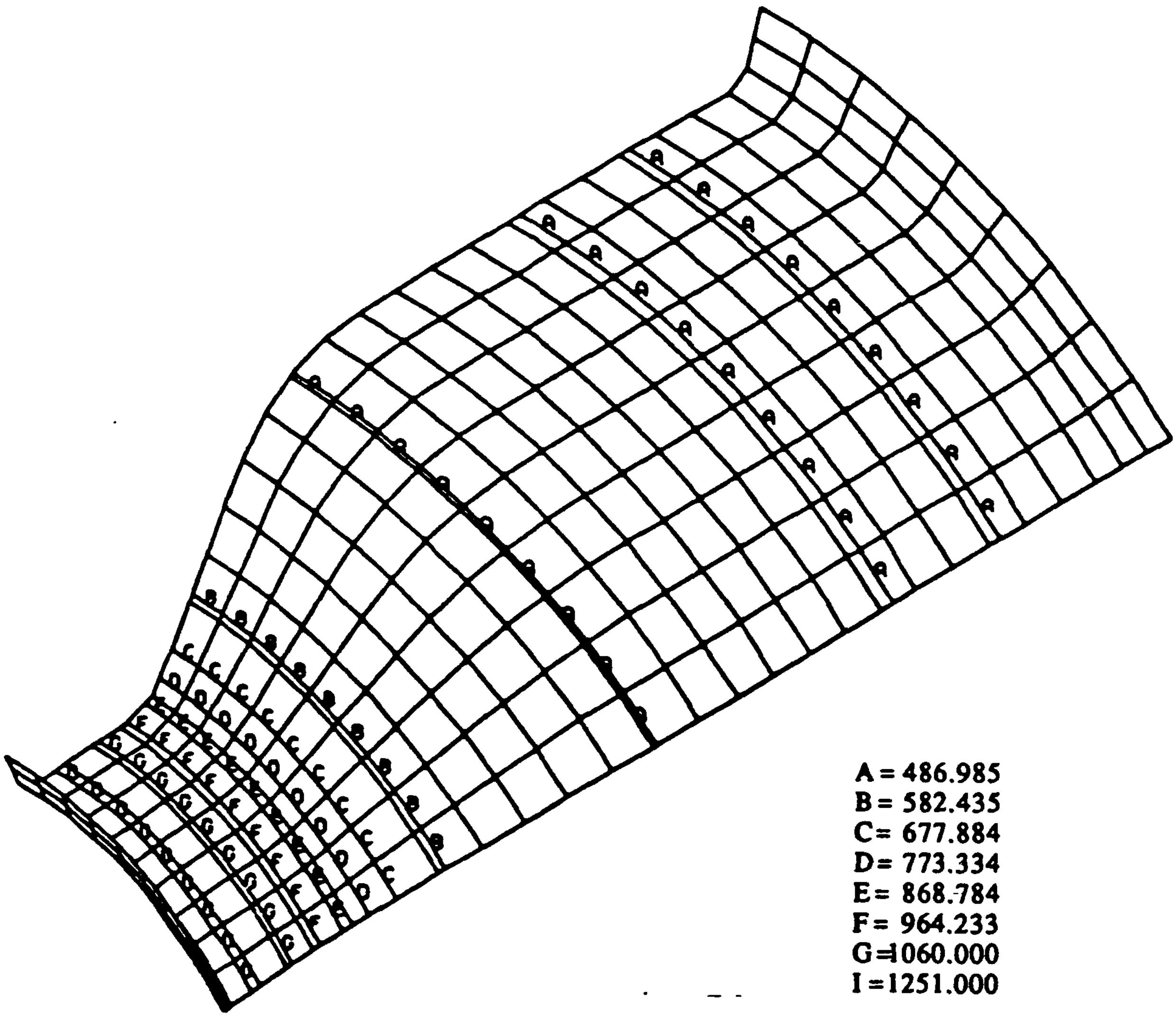



Figure 3-10 Temperature Distribution - Standard Day Load Condition

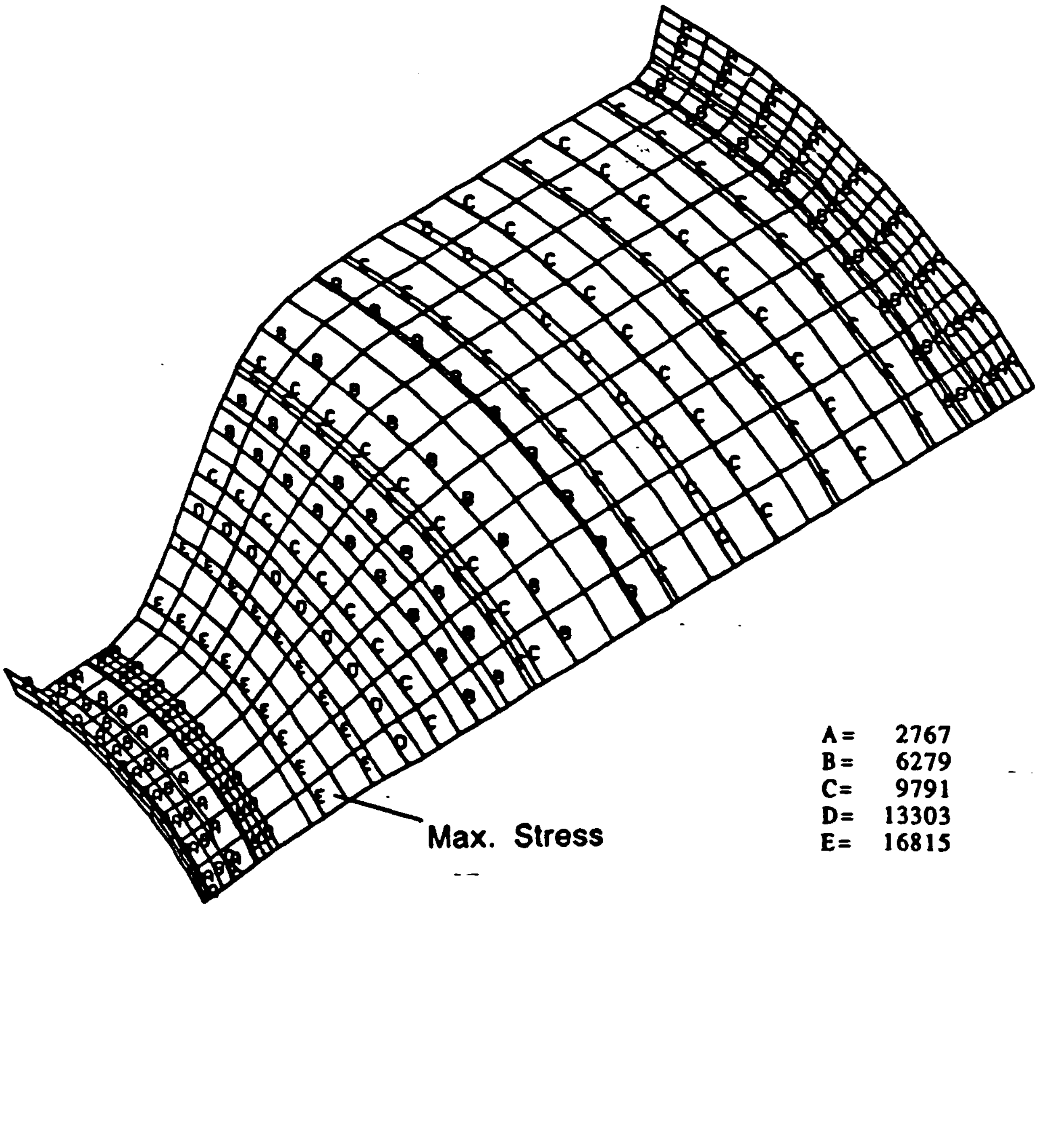



Figure 3-11 Maximum Equivalent Stress - Standard Day Load Condition
All Hastelloy X Combustor

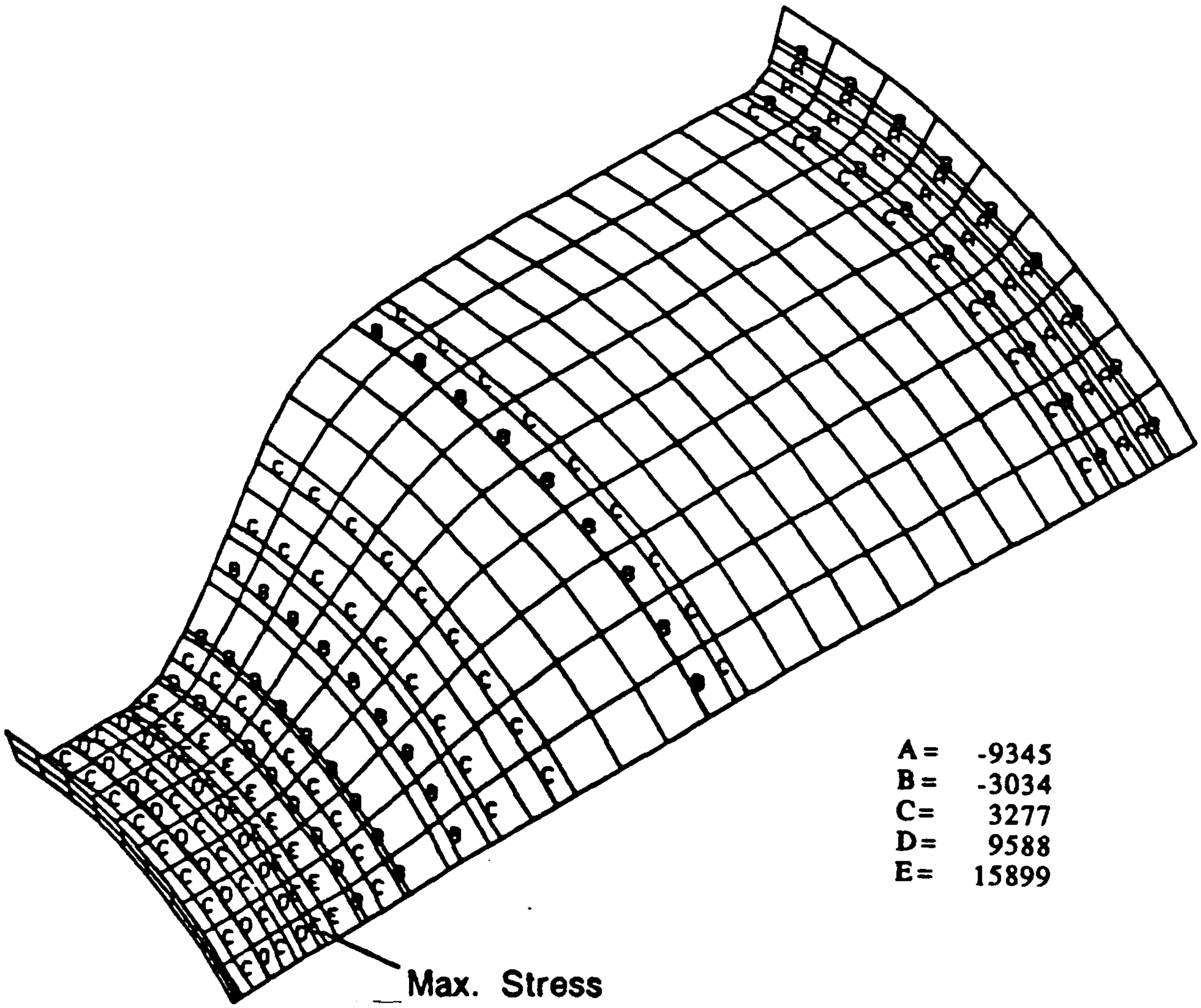



Figure 3-12 Maximum Bending Stress - Standard Day Load Condition
All Hastelloy X Combustor

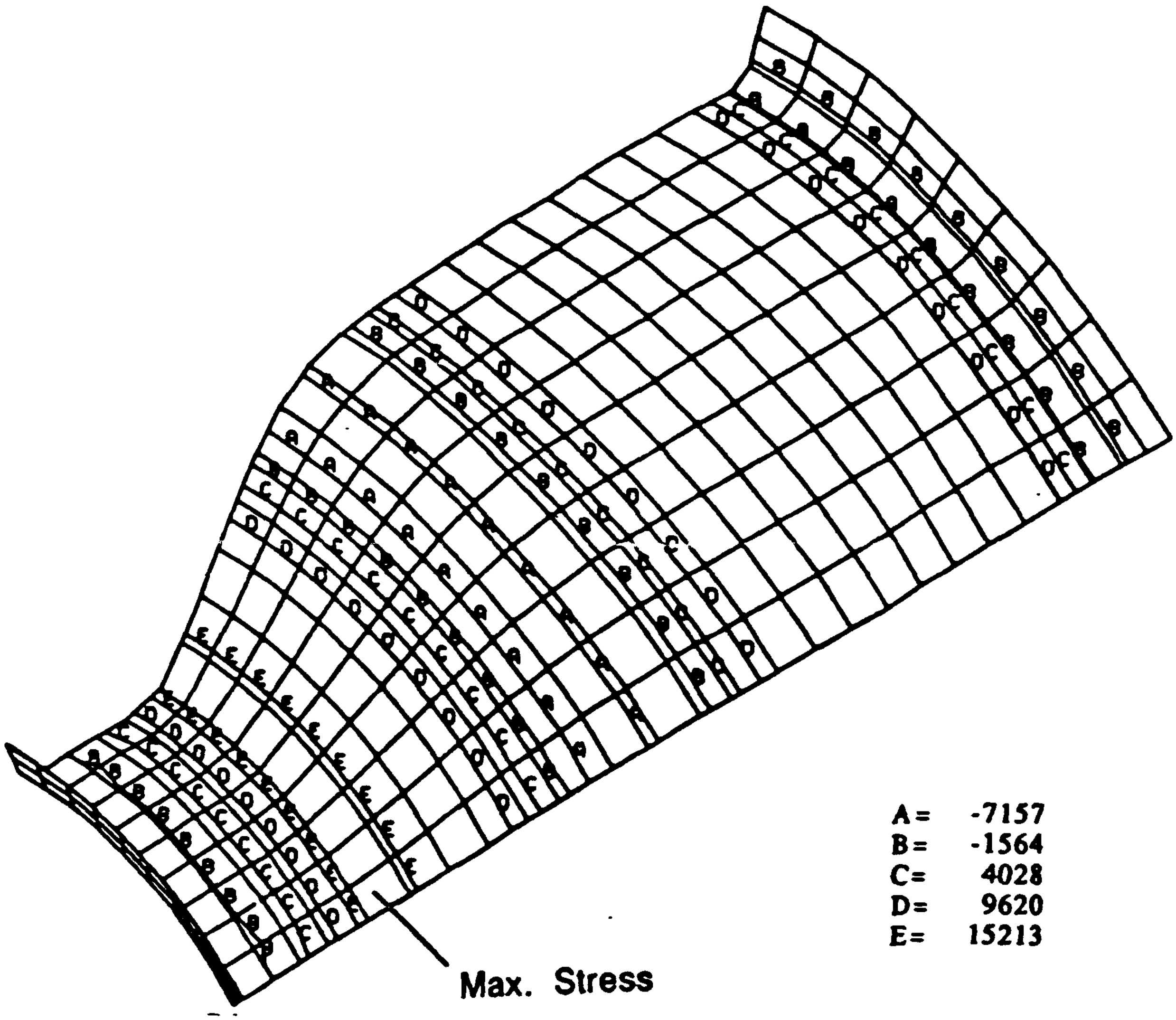



Figure 3-13 Maximum Hoop Stress - Standard Day Load Condition
All Hastelloy X Combustor

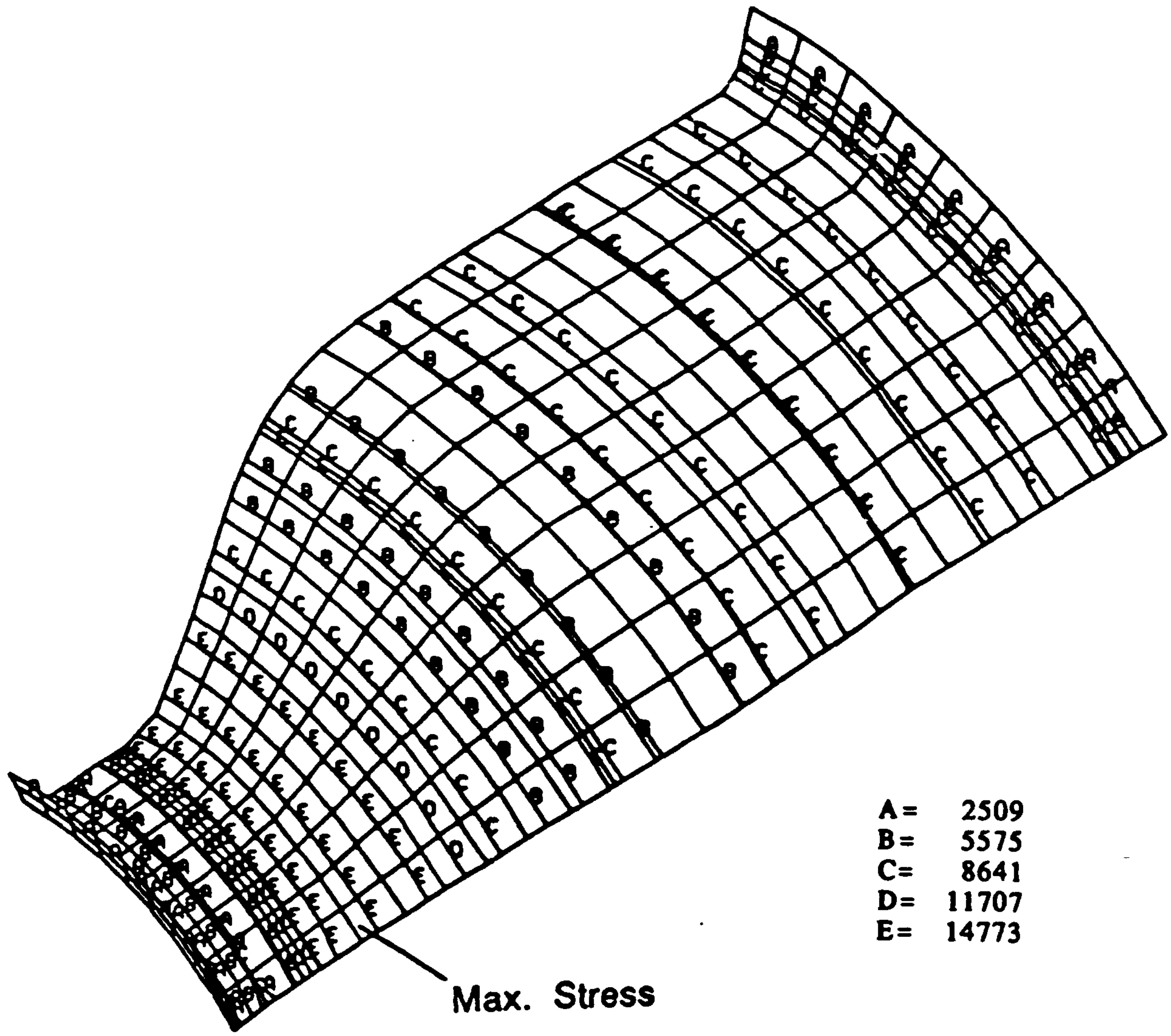



Figure 3-14 Maximum Equivalent Stress - Hot Day Load Condition
All Hastelloy X Combustor

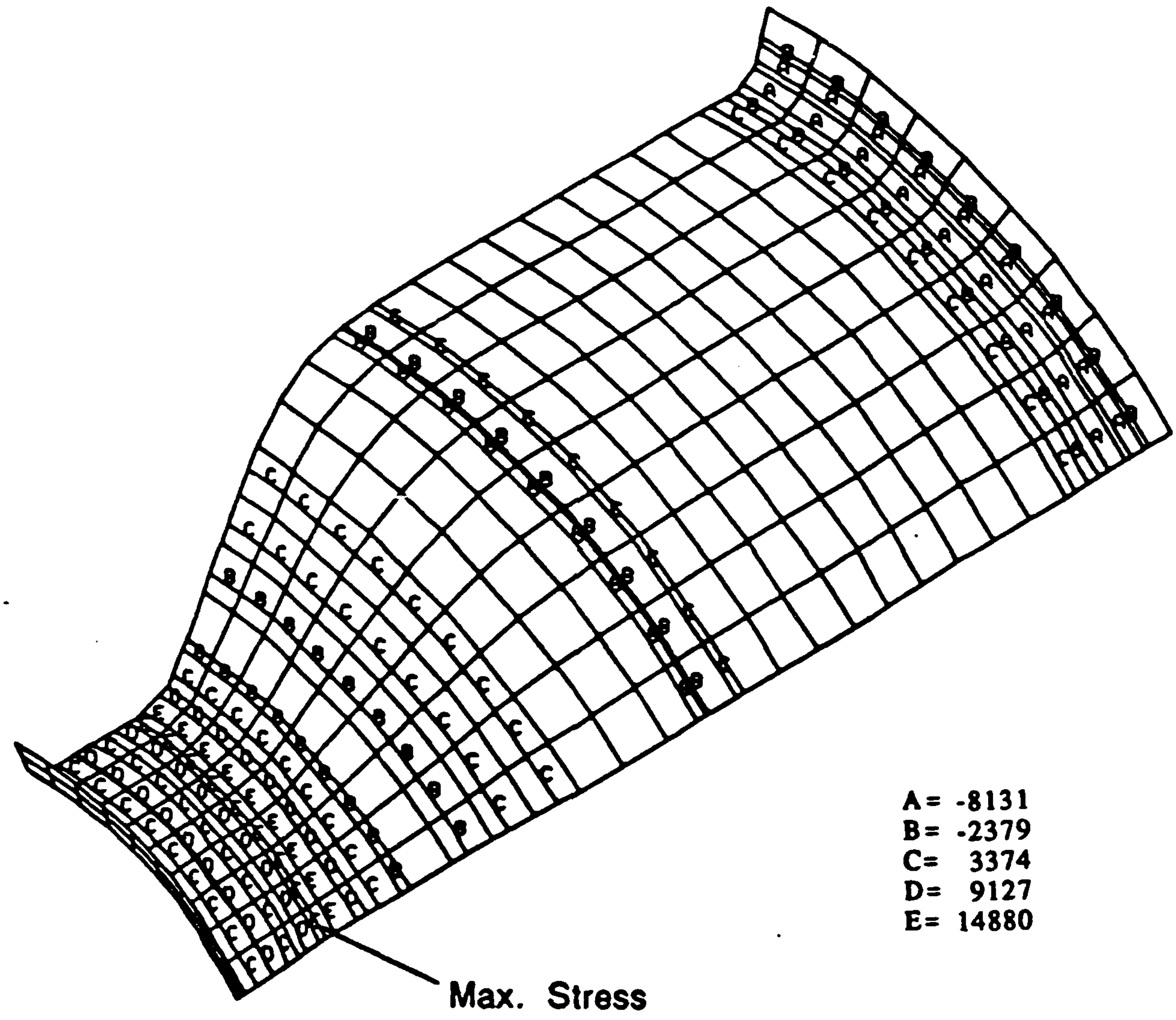



Figure 3-15 Maximum Bending Stress - Hot Day Load Condition
All Hastelloy X Combustor

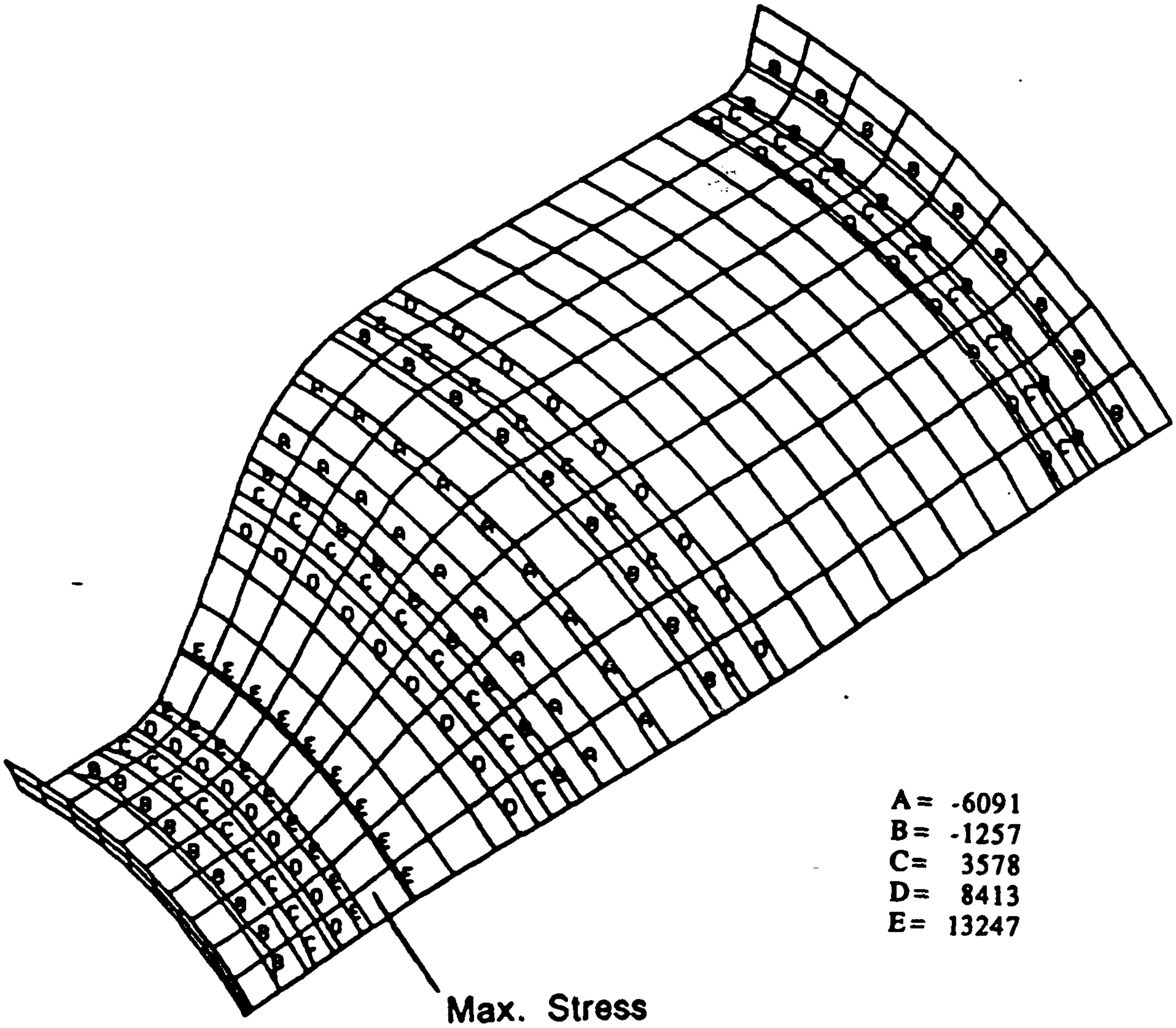



Figure 3-16 Maximum Hoop Stress - Hot Day Load Condition
All Hastelloy X Combustor

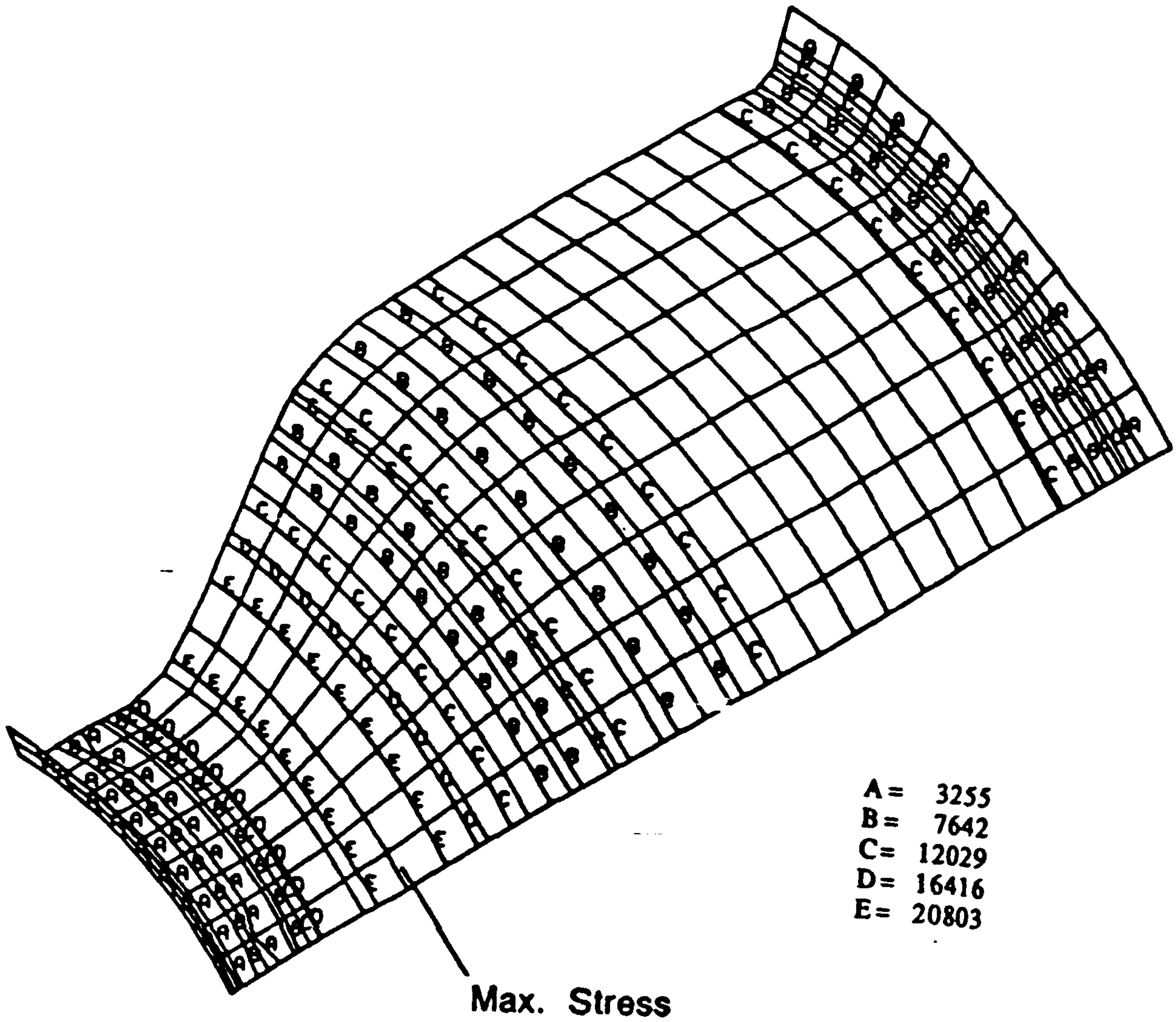



Figure 3-17 Maximum Equivalent Stress - Cold Day Load Condition
All Hastelloy X Combustor

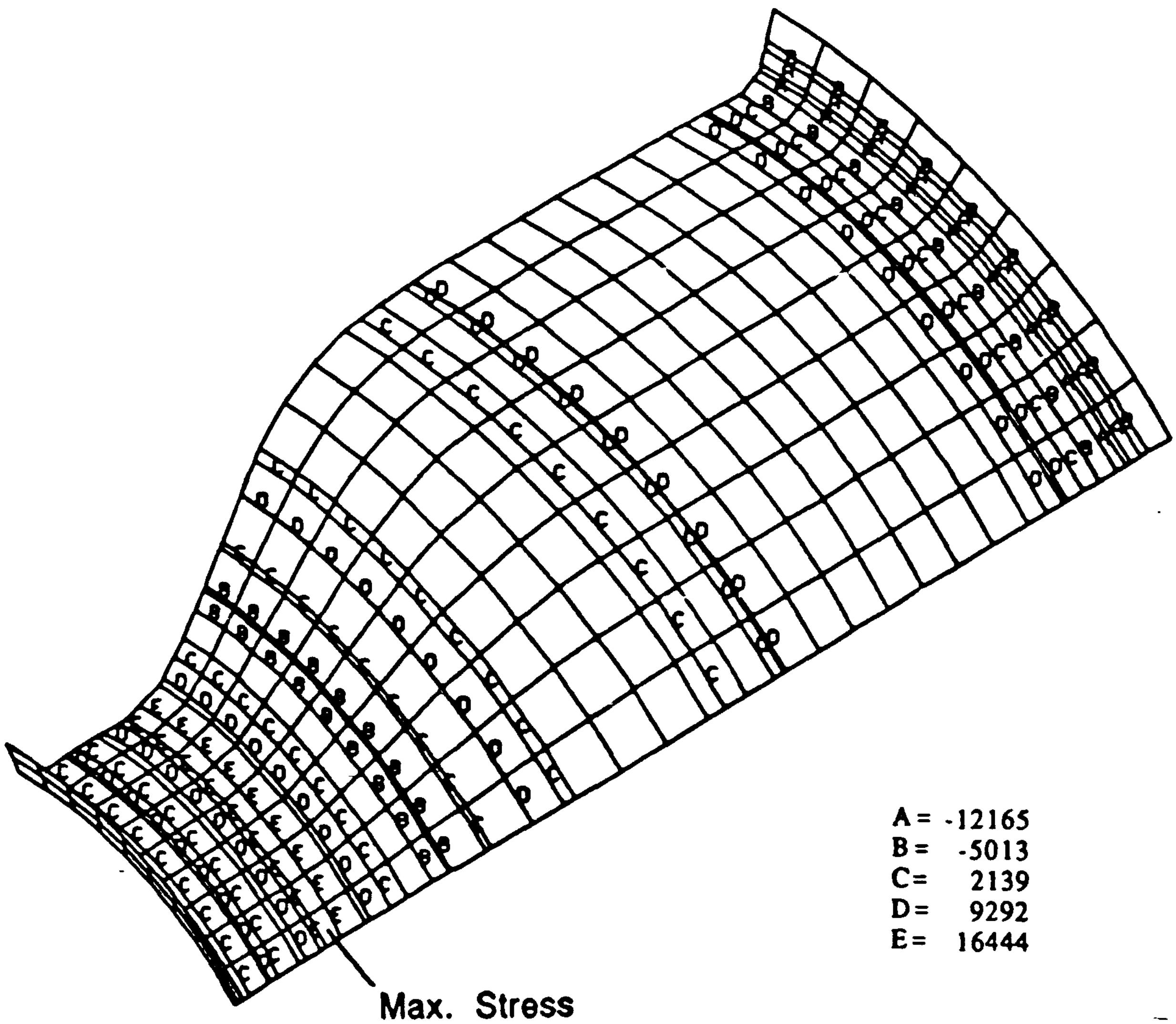



Figure 3-18 Maximum Bending Stress - Cold Day Load Condition
All Hastelloy X Combustor

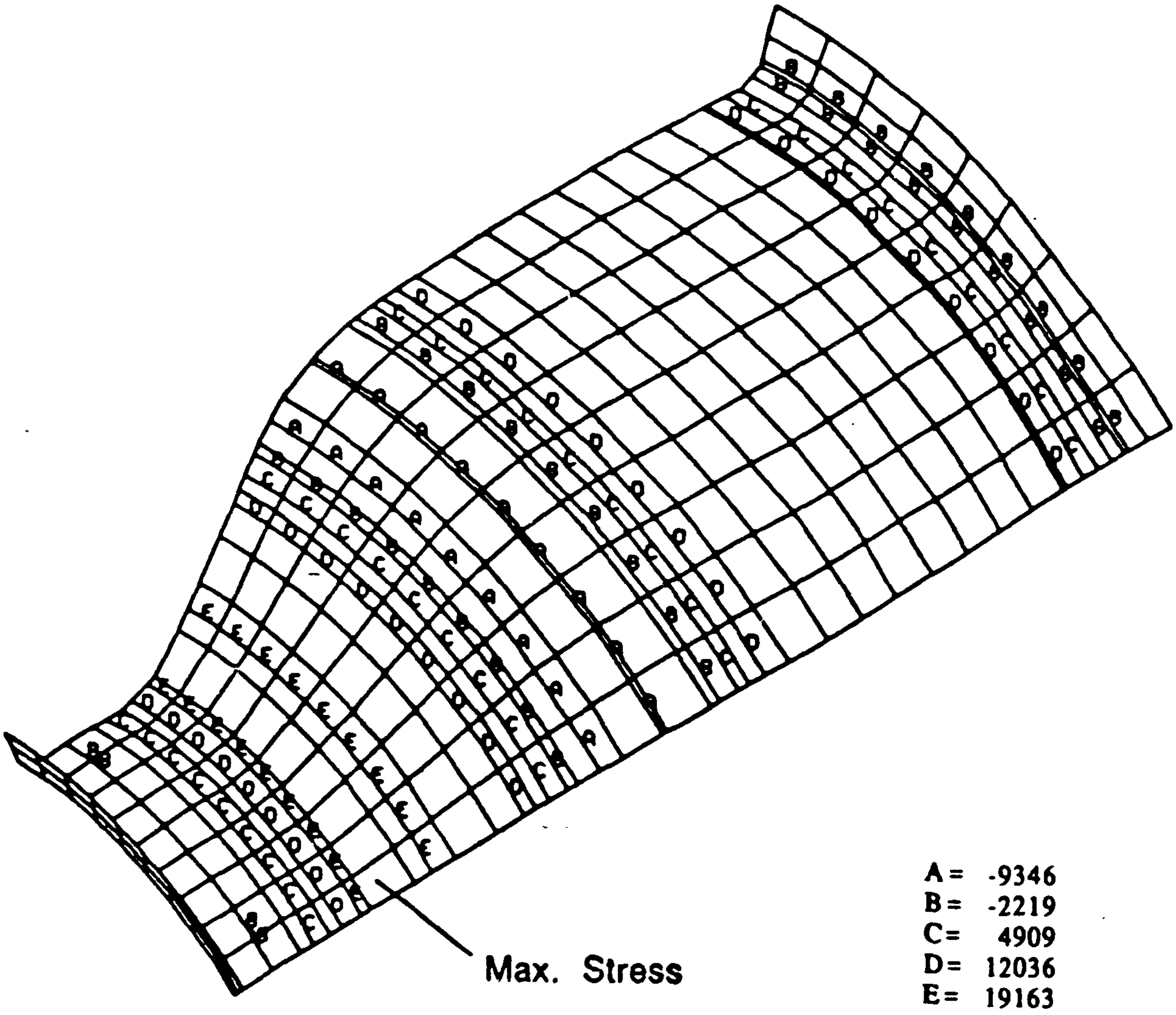



Figure 3-19 Maximum Hoop Stress - Cold Day Load Condition
All Hastelloy X Combustor

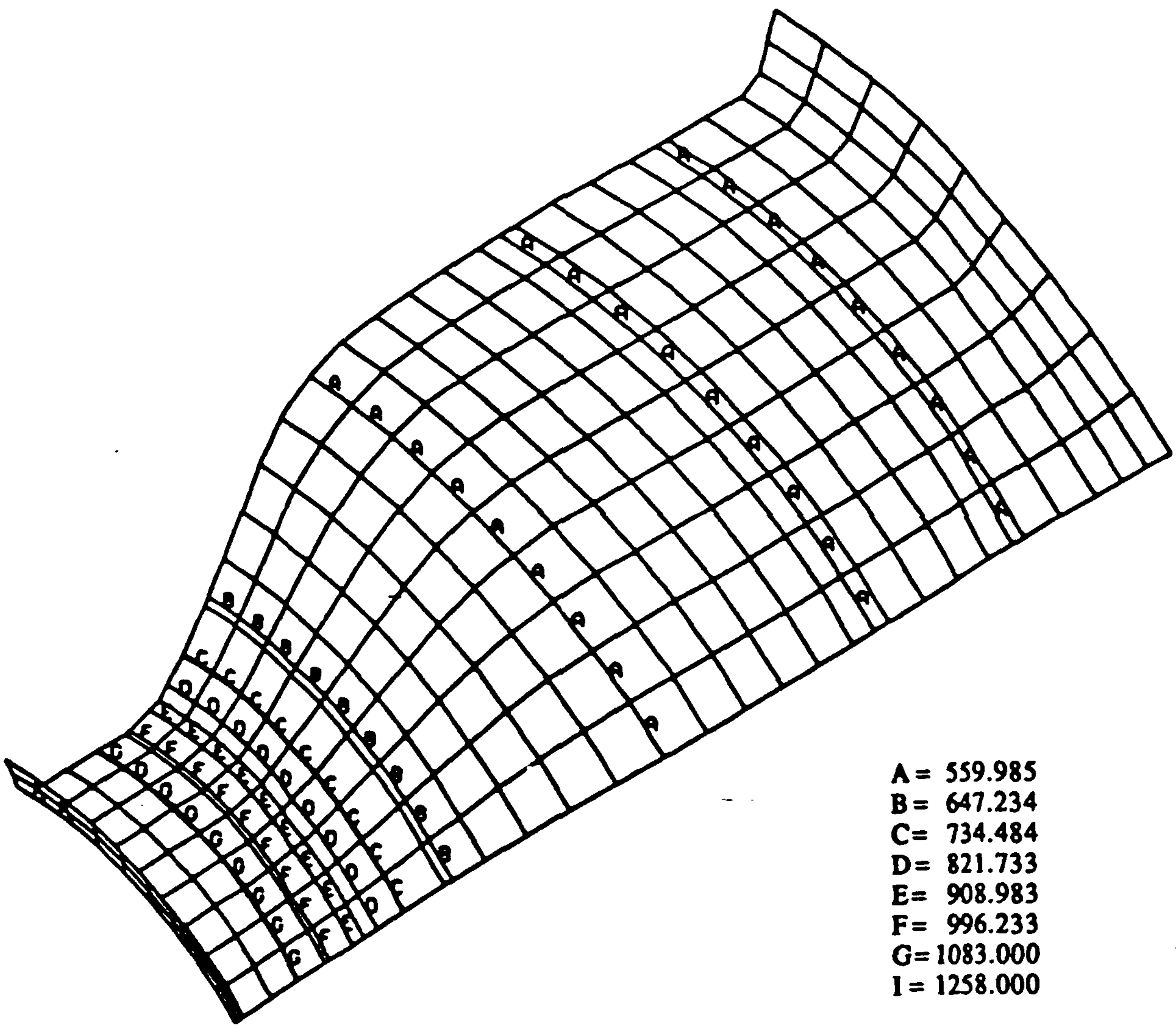



Figure 3-20 Temperature Distribution - Hot Day Load Condition
All Hastelloy X Combustor

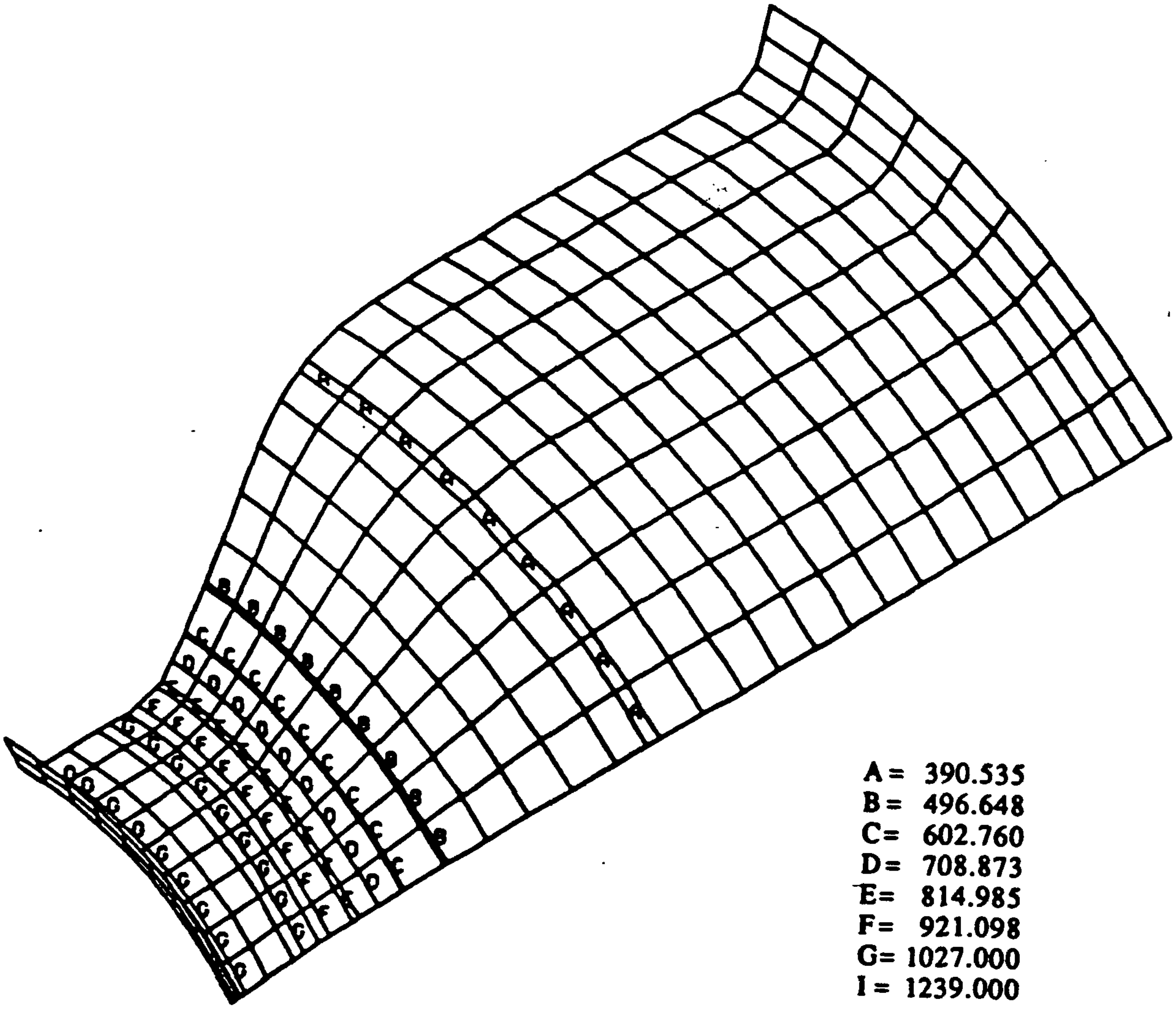



Figure 3-21 Temperature Distribution - Cold Day Load Condition
All Hastelloy X Combustor

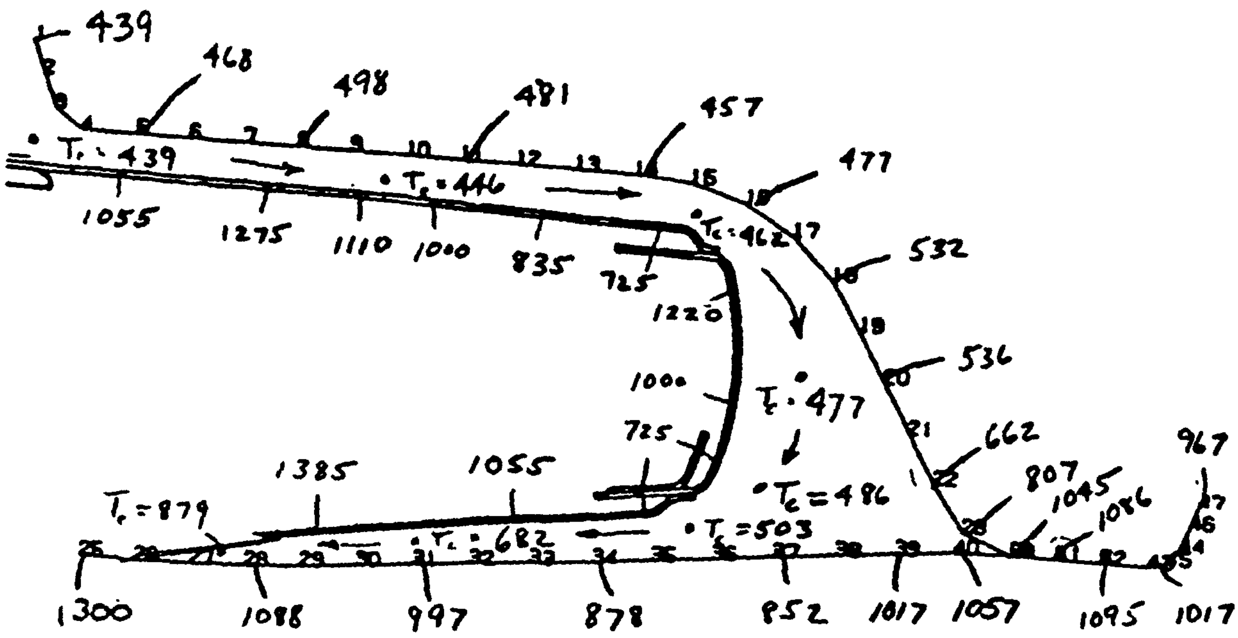



Figure 3-22 Thermal Analysis For Standard Day

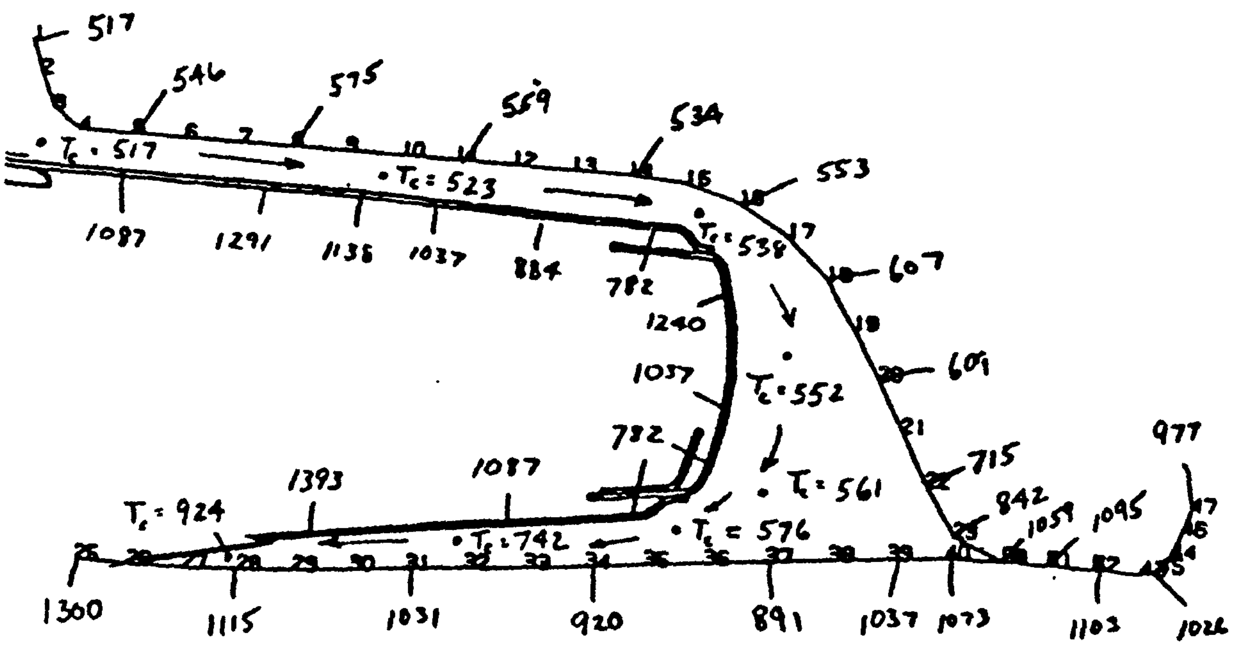



Figure 3-23 Thermal Analysis For Hot Day

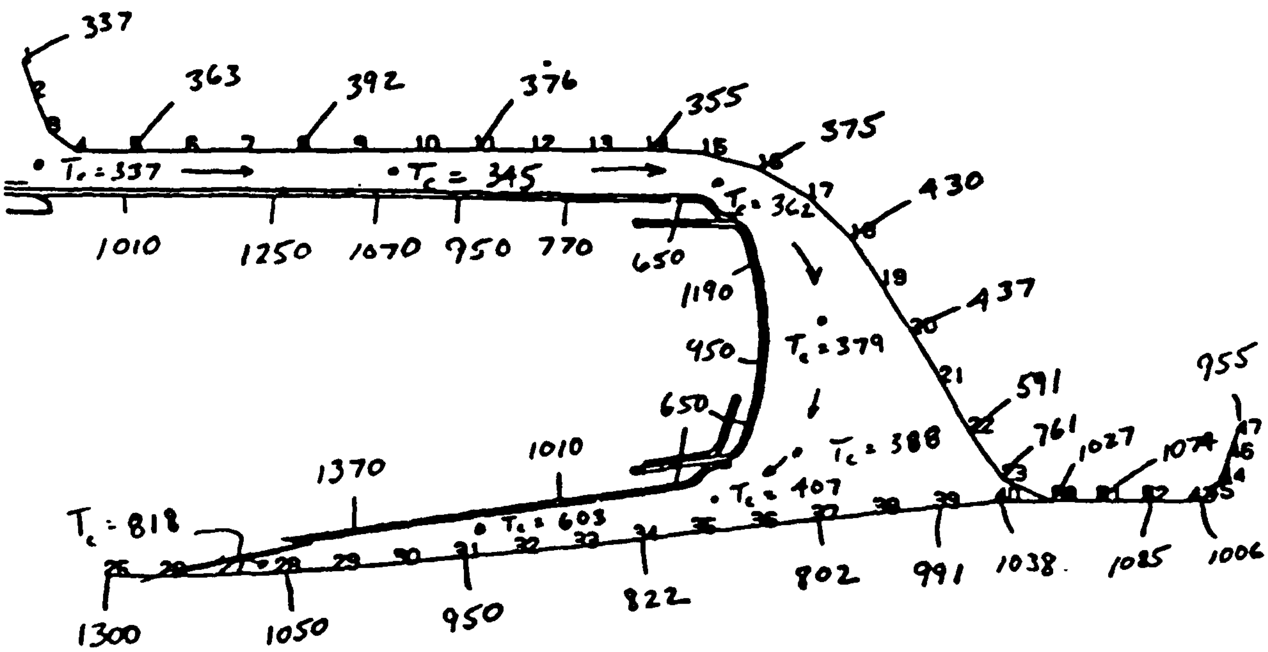



Figure 3-24 Thermal Analysis For Cold Day

# 4.0 FLOW FORM TECHNOLOGY

## 4.1 TECHNICAL APPROACH

The approach to flow forming consists of (1) the actual development of mechanically forming material to the combustor housing configuration and (2) evaluate the effects of flow forming on the mechanical properties of the material selected for use.

### 4.1.1 FLOW FORMING, WHAT IS IT?

Flow forming, also known as flow turning, hydro spinning, power spinning, shear spinning, and roll forming is a cold extrusion method of metal working. In this process a piece of metal takes the shape of a hardened steel rotating mandrel by virtue of extrusion under the action of forming rollers. Parts are produced which are round in cross section, but which may be straight-sided, cones, contoured cones, cylindrical shaped parts, or combinations of the above. The wall thickness is predetermined by mathematical equation varying and is closely controlled. Wall thicknesses can vary along the shape of the part to provide material where needed to meet strength or design requirements.

Flow forming is often confused with spinning. There is, however a very basic difference in conventional spinning and flow forming, even if spinning machines of today are equipped with tracer control and hydraulics. Spinning utilizes a relatively thin piece of starting material and produces the shape of the finished part from a larger diameter starting blank than the largest diameter of the finished part. This is very similar to deep drawing. No reduction of the wall thickness is contemplated, but is often experienced and is very difficult to control.

## 4.2 FLOW FORMING DEVELOPMENT

The new housing design is a one piece configuration with varying wall thicknesses to minimize the use of reinforcing doublers using Hastelloy X material. The manufacturing goal was to fabricate this new design from start to finish using flow forming techniques, thereby minimizing fabrication time and costs.

### 4.2.1 EXISTING CAPABILITY

A team was formed to survey the industry and determine if 100% flow forming capability existed. There are several manufacturers that do flow forming, but none have formed Hastelloy X material to the demanding configuration of the Sundstrand combustor housing. All forming houses refused to bid on manufacturing housings to the new one-piece design, except Precision Metal Forming Industries (PMF). PMF proposed to manufacture housings to the one-piece design, but would achieve the final configuration thru a combination of deep draw and flow forming, reference Section 4.3.

### 4.2.2 FORMING DEVELOPMENT

An initial set of housings were fabricated using the combination method proposed by PMF. These housings were sent to Engineering Materials and Processes for analysis and evaluation, reference Section 4.4. Some cracks and laps were discovered in these units. After modifications to the forming process, PMF was able to fabricate combustor housings without discrepancies.

### 4.2.3 UNIT/ASSEMBLY WEIGHT ANALYSIS

A weight analysis was performed comparing the existing housing assembly design to the new one-piece design. In addition, actual weighing of both designs was accomplished.

Results of analysis and actual testing were very close. The existing design contains more separate parts and has thinner wall thicknesses. The new proposed one-piece design contains fewer parts, but heavier wall thicknesses. The final weight between the two designs is almost the same. At worst, the new design is 2 ounces heavier. Both designs use brazing as a means of metal joining. When laser welding is incorporated, the new design will be a fraction lighter.

## 4.3 DETAIL FABRICATION

### 4.3.1 HOUSINGS IN SUPPORT OF PHASE II DEVELOPMENT

The housings manufactured in support of the IMIP Phase II development were fabricated by means of a combination of both deep draw and flow forming operations as discussed above in Section 4.2. The steps used in the forming process are shown in Figure 4-3-1.

STEP 1 Start with a a sheet of Hastelloy X material .090 inches thick with a 16.5 inch diameter.

STEP 2 Make the initial deep draw shape using a 100 - 300 ton hydraulic press.

STEP 3 It was established during the the metallurgical evaluation, Section 4.4, that an annealing operation needed to be accomplished before the second draw operation to prevent material cracks.

STEP 4 The second draw operation increased the cylindrical wall thickness to .095 inches and established the initial shape required for flow forming.

STEP 5 The flow forming operation was accomplished using a Cincinnati Flow Turn Lathe. This operation established the basic length of the housing and the critical wall thicknesses.

STEP 6 Another annealing operation was added to prepare the material for the final two sizing operations.

STEP 7 This operation is accomplished using the 100 - 300 ton press to form the reverse curve of the housing. The material is cold formed between two dies.

STEP 8 This is the last forming operation. This sizing operation again uses two dies to form the final shape of the combustor housing.

STEP 9 This operation uses a conventional engine lathe to trim the forward flange and to cut off the unused portion of the housing at the exhaust end.

4.3.1.1 LASER MACHINING

The housing is sent to Laser Industries after all forming is complete for cutting openings in the combustor housing and final trimming. The openings are for the various ports required in the combustor design.

4.3.1.2 MISCELLANEOUS PARTS

All bosses were fabricated by outside vendors. This will not change from the existing design, except that the bosses have much smaller attach flanges and are coined or formed to the housing contour for direct attachment since most doublers have been eliminated. Figure 4-3-2 shows the various finished parts of the new housing design prior to assembly. the conical shaped part is the diffuser. Figure 4-3-3 shows the completed combustor housing assembly.

4.3.2 FINAL FORMING METHOD PLANNED FOR COMBUSTOR FABRICATION

The planned Precision Metal Forming cell will be a complete stand alone facility capable of fabricating major combustor housing details from sheet stock ready for major assembly.

The sequence of operations used to fabricate the Phase II units are discussed in Section 4.3.1. The sequence of operations that will be employed in the new Precision Metal Forming Cell will further enhance manufacturing technology.

4.3.2.1 COMBUSTOR HOUSINGS AND DIFFUSERS

Raw sheet stock will be sheared square and blanked to round discs as in Section 4.3.1. The flow form lathe (BOKO 3D 55/CNC-R3.1, see Section 6.0 in equipment selection) is capable of flow forming a complete housing or diffuser from a flat blank, thereby eliminating the pre-form operation and post flow turn final sizing, see Figures 4-3-4 and 4-3-5. BOKO has successfully demonstrated this machine tool capability. After the details have been flow turned complete, a functional gauge will be used to inspect dimensions and track any deviation using statistical process control.

Laser machining will be accomplished on our Lumonics Custom Modle laser center. Laser machining parameters have been developed, reference Section 5.0.

The laser unit will trim the housing and diffuser to length and trim the outside diameter of the flange. All holes are to be laser drilled for positioning of all subsequent bosses.

The machine specification and selection included a successful demonstration of laser welding all joints.

Laser welding does promise to show significant savings in the future, however we will have to develop in this technology. All bosses will be procured from outside vendors with numerical controlled lathes. Bosses will be "coined" or formed to match the outside contour of the flow formed housing.

Subsequent assembly will utilize assembly fixtures to locate all details in position. Resistance welding will be used to attach details in place. All joints will be loaded with braze alloy and brazed in our vacuum furnace. Final qualification and adjustments are then accomplished. Major assemblies are then ready for engine build.

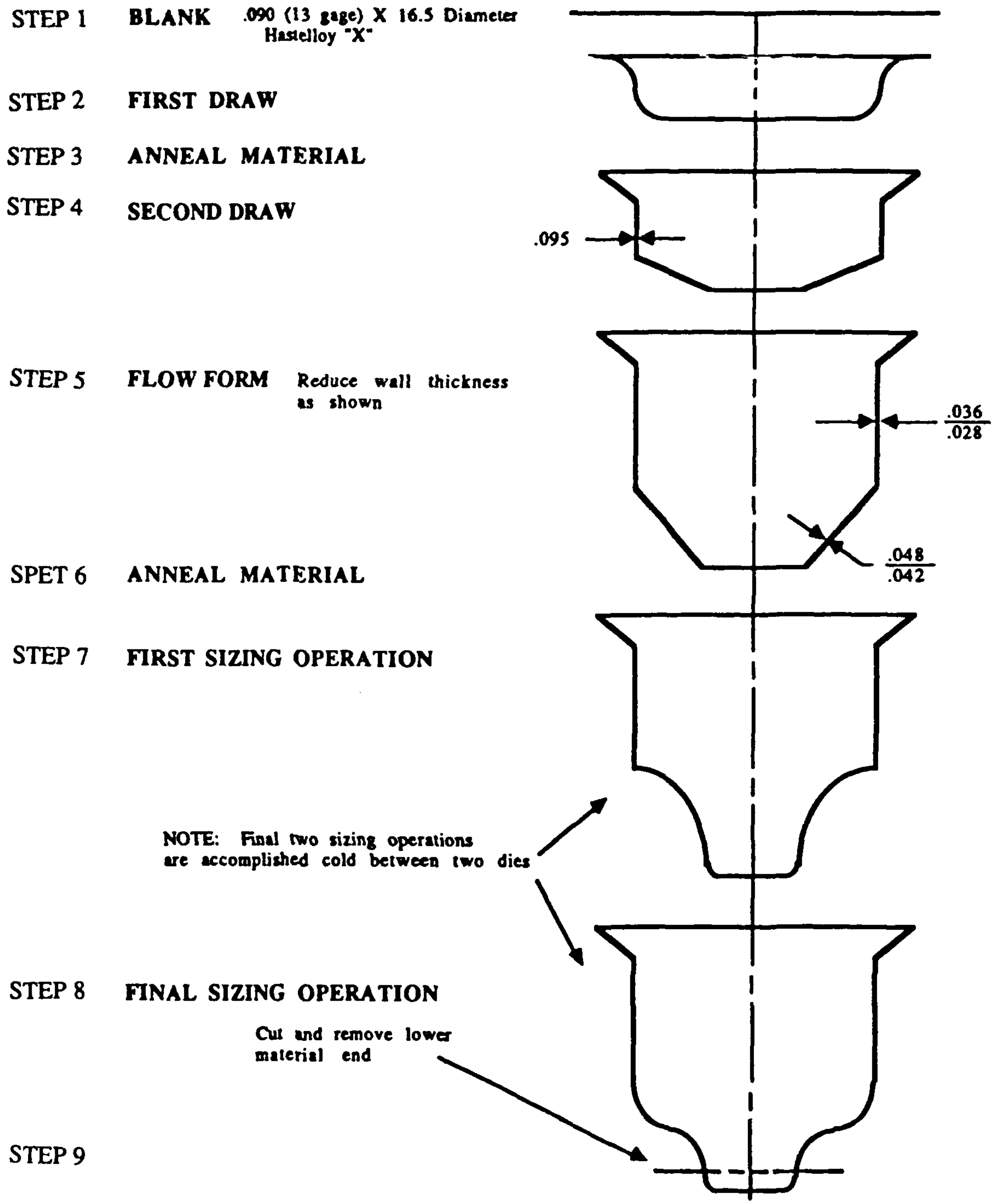



Figure 4-3-1 Forming Operations For Housing

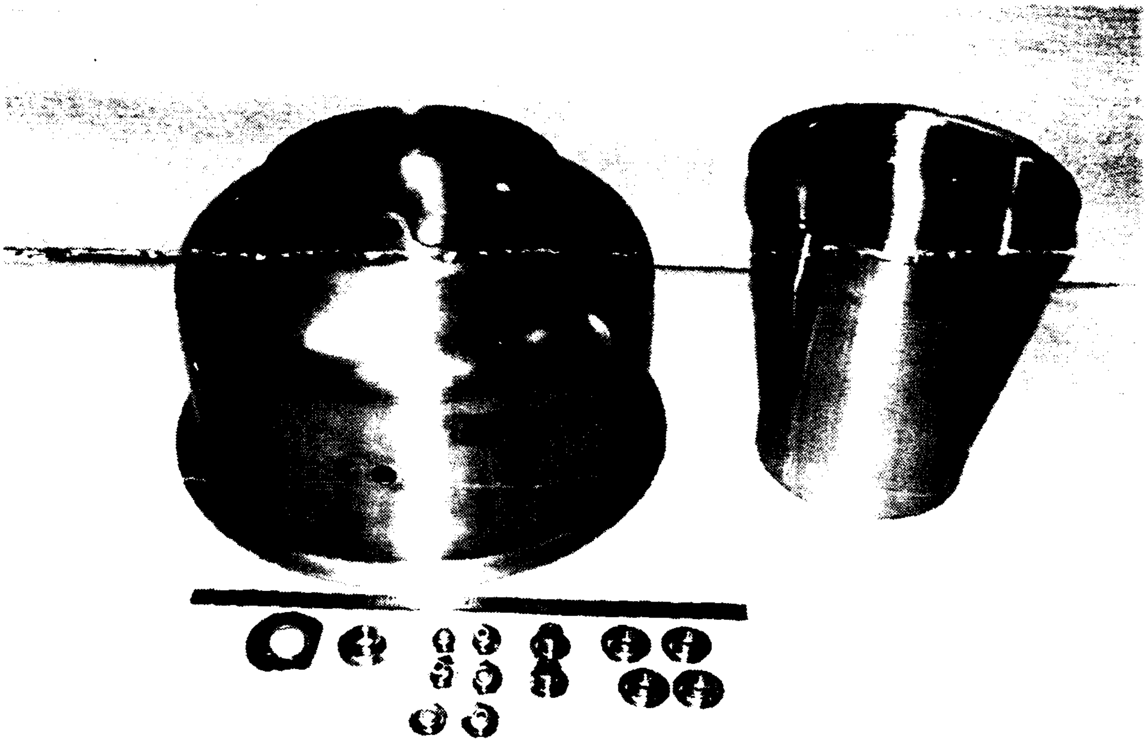


Figure 4-3-2 Basic Housing Parts

Figure 4-3-3 Complete Combustor Assembly

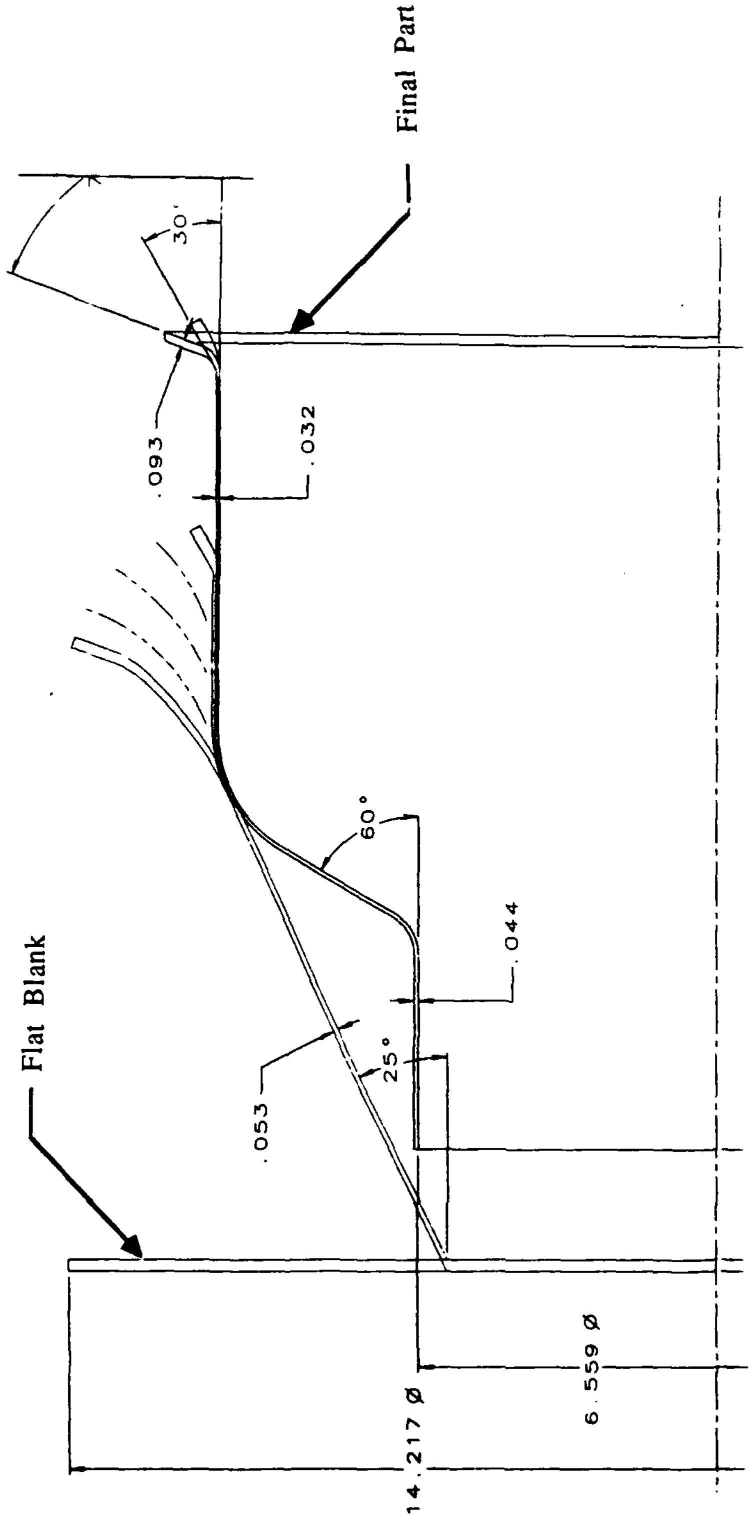



Figure 4-3-4 Housing Is Flow Formed In One Programmed Continuous Operation From A Flat Blank

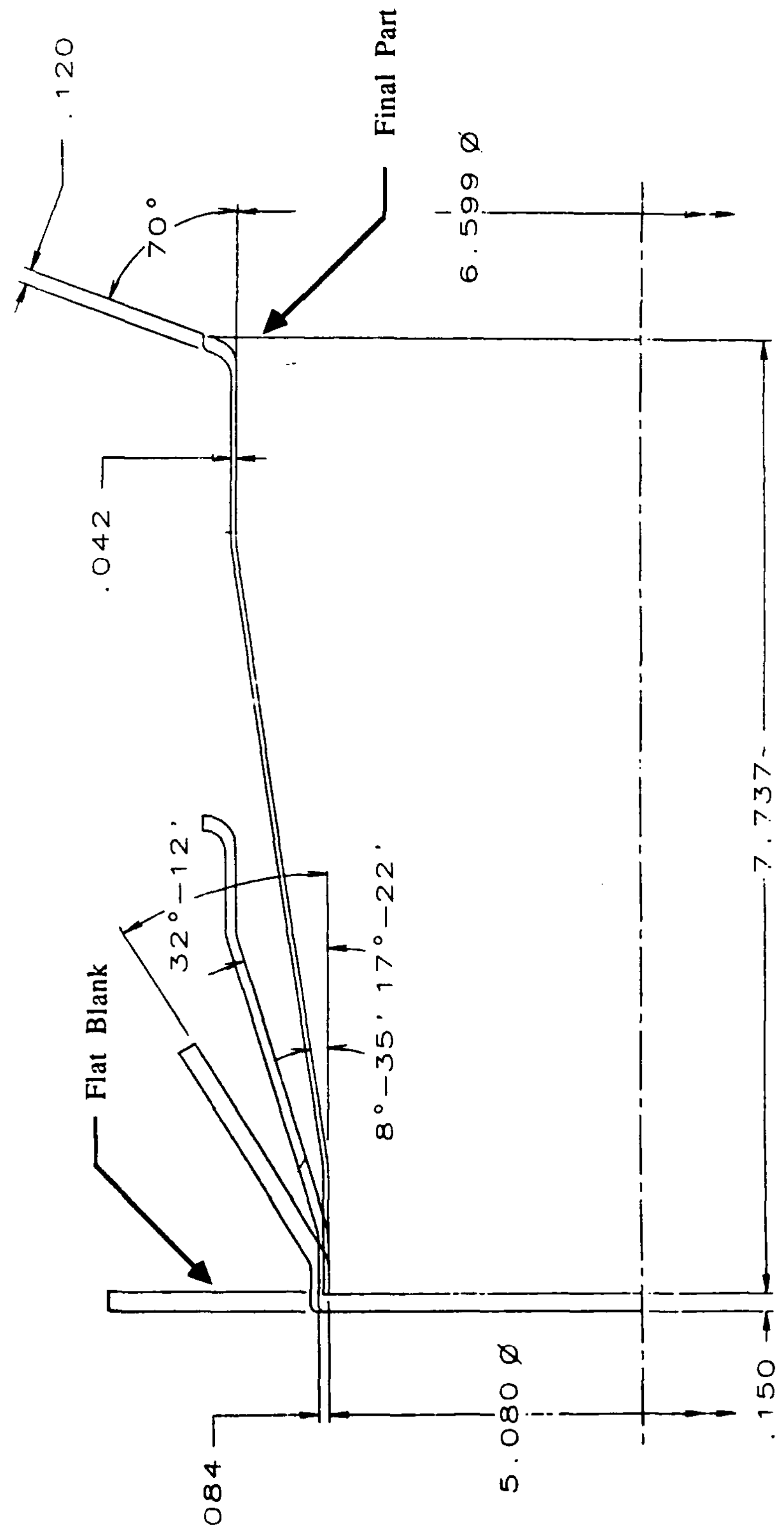



Figure 4-3-5 Diffuser Is Flow Formed In One Programmed Continuous Operation From A Flat Blank

## 4.4 METALLURGICAL EVALUATION

A metallurgical evaluation was initiated to determine the effects of flow forming on the mechanical properties of the Hastelloy X combustor case. The evaluation consisted of a metallographic examination and mechanical property analysis of a combustor case to the requirements of the Hastelloy X material specification AMS 5536.

### 4.4.1 EFFECTS OF BRAZING ON FLOW FORMED HASTELLOY X COMBUSTOR HOUSINGS

The material properties of the flow formed combustor after being exposed to a AMI 915 braze cycle were compared to the material specification AMS 5536. Evaluating the material properties after brazing will reflect the condition of the material in service. This testing included:

1. Metallographic Examination
2. Tensile
3. Stress Rupture
4. Bend
5. Chemical Composition

#### 4.4.1.1 METALLOGRAPHIC EXAMINATION

AMS 5536 requires that sheet material under 0.125 inches thick have a grain size of ASTM No. 4 or finer. The microstructure of the as-received flow formed combustor housing varied from a grain size of ASTM No. 3 with a significant amount of deformation in the annealing twins near the exhaust end of the combustor housing (Area A, Figures 4-4-2 and 4-4-3) to ASTM No. 1.5 with very little deformation in the annealing twin in the flange of the case (Area B, Figures 4-4-2 and 4-4-4). Grain growth in the flange is to be expected because the material in the flange was annealed twice at 215 degrees F without being cold worked during the drawing and flow forming operations.

After being exposed to the braze cycle the material near the exhaust end recrystallized to an ASTM No. 5.5 grain size (Figures 4-4-3 and 4-4-5). Recrystallization indicates the material had greater than 6% cold work (ref., Universal Cyclops vendor information literature). There was no noticeable change in the microstructure of the Hastelloy X material in the flange (Figures 4-4-4 and 4-4-6).

#### 4.4.1.2 TENSILE

The tensile properties conformed to the requirements of AMS 5536 (Figure 4-4-2 and Table I). One of the specimens was under the low limit for tensile strength and elongation but results of a retest of a specimen taken from an identical area was satisfactory.

#### 4.4.1.3 STRESS RUPTURE

The stress rupture test results conformed to the requirements of AMS 5536 (Figure 4-4-2 and Table II).

#### 4.4.1.5 CHEMICAL COMPOSITION

Quantitative spectrographic analysis verified that the material met the requirements of AMS 5536.

### 4.4.2 FLOW FORMED COMBUSTOR HOUSING SURFACE QUALITY

During the development of the formed combustor housing, penetrant indications were observed on 50% of the initial run of twenty-four housings. The housing is formed from a 0.909 inch wall thickness to 0.032 inch wall thickness in some areas. The indications were evaluated to determine the type of discontinuity.

The forming operation was broken up into two steps with an anneal operation in between. This increased the material ductility and eliminated the cracking and laps.

#### 4.4.2.1 VISUAL EXAMINATION

Visual examination revealed that the indications were confined to two areas of the housing. One area was a 0.5 inch band which was near the middle of the 11 inch I.D. and extended around 2/3 of the circumference (Figure 4-4-7). These indications were perpendicular to the axis of the housing. The second location was the radius (Figure 4-4-7). These locations were parallel to the axis of the housing.

#### 4.4.2.2 SEM EXAMINATION

SEM examination revealed that the indications on the radius were identified as cracks (Figure 4-4-8). One of the cracks was broken open for examination. The length of this crack was .050 inches and the depth was .008 inches (Figure 4-4-9).

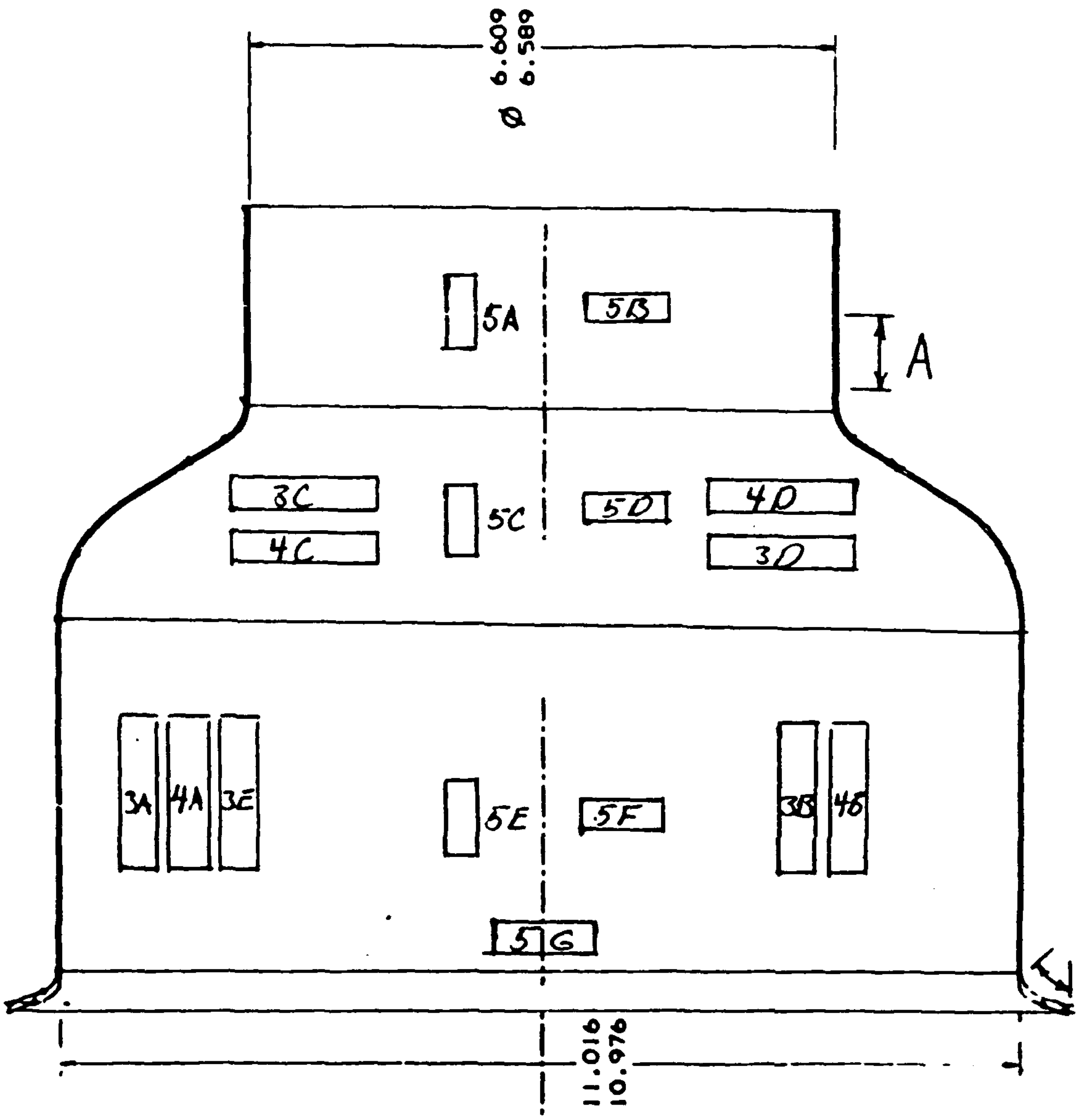
The indications in the 0.5 inch band were also examined on the SEM. The indications were identified as laps (Figure 4-4-10).

#### 4.4.2.3 METALLOGRAPHIC EXAMINATION

Metallographic examination of the indications in the 0.5 inch band confirmed that the indications were in fact laps which were .005 inches deep (Figure 4-4-11). No material abnormalities were noted which would have contributed to the formation of the laps or cracks.

### 4.4.3 CONCLUSIONS AND RECOMMENDATIONS

After modifying the forming operation to include two annealing operations the surface cracks and laps were eliminated. The material near the exhaust end of the combustor housing had cold worked over 6%. This was traced to two sizing operations (Figure 4-3-1). These sizing operations are done after the final anneal and affect only the exhaust end of the combustor housing. Exposure to an AMI 915 braze cycle stress relieves the material via recrystallization. No distortion occurred after brazing, therefore, no anneal was recommended after the sizing operations since the braze cycle anneals the material.




3"X" - Tensile Specimens
4"X" - Stress Rupture Specimens

Figure 4-4-2 A sample cross section of the combustor case illustrating the location of the mechanical property test specimens and the location of the metallographic examination (Areas A and B).

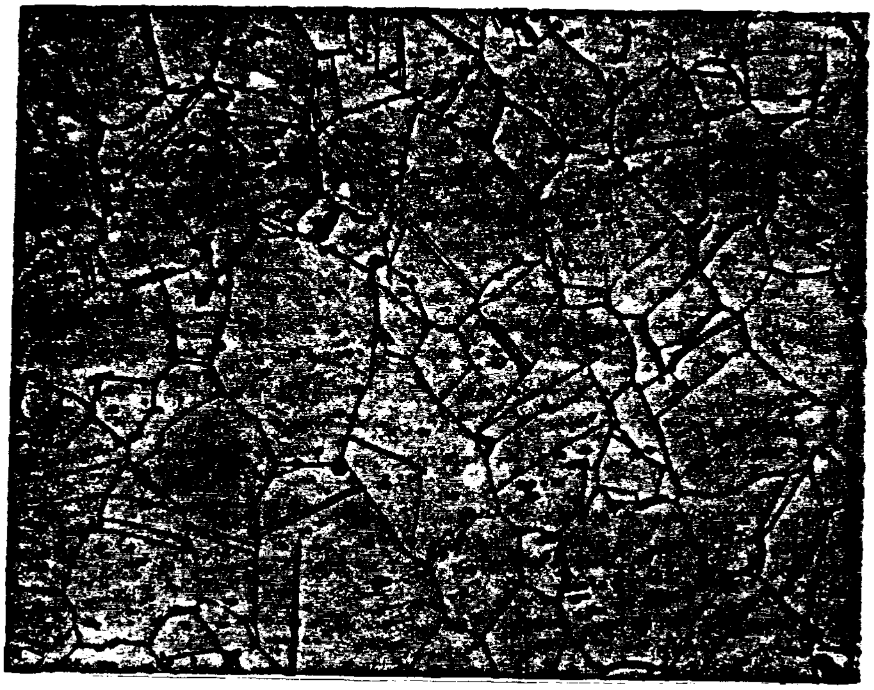


Figure 4-4-3 Metallographic cross section taken from area A (Figure 2) of the flow formed combustor case in the as-received condition. Grain size is ASTM No. 3.0. Mt. No. 90-557, Mag: 100X, Etchant: Electrolytic, 10% Oxalic Acid

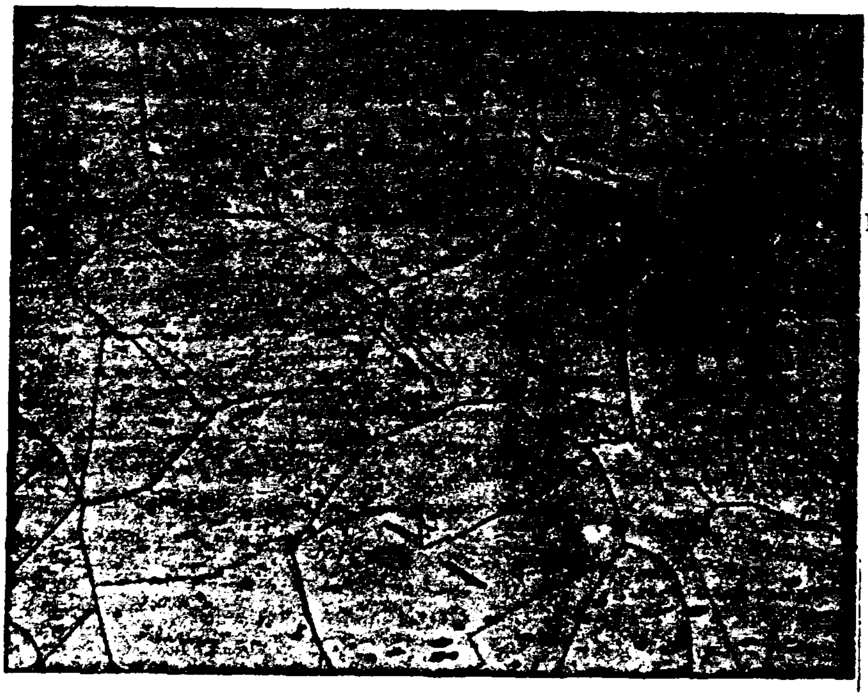


Figure 4-4-4 Metallographic cross section taken from area B (Figure 2) of the flow formed combustor case in the as-received condition. Grain size is ASTM No. 1.5. Mt. No. 90-562, Mag: 100X, Etchant: Electrolytic, 10% Oxalic Acid

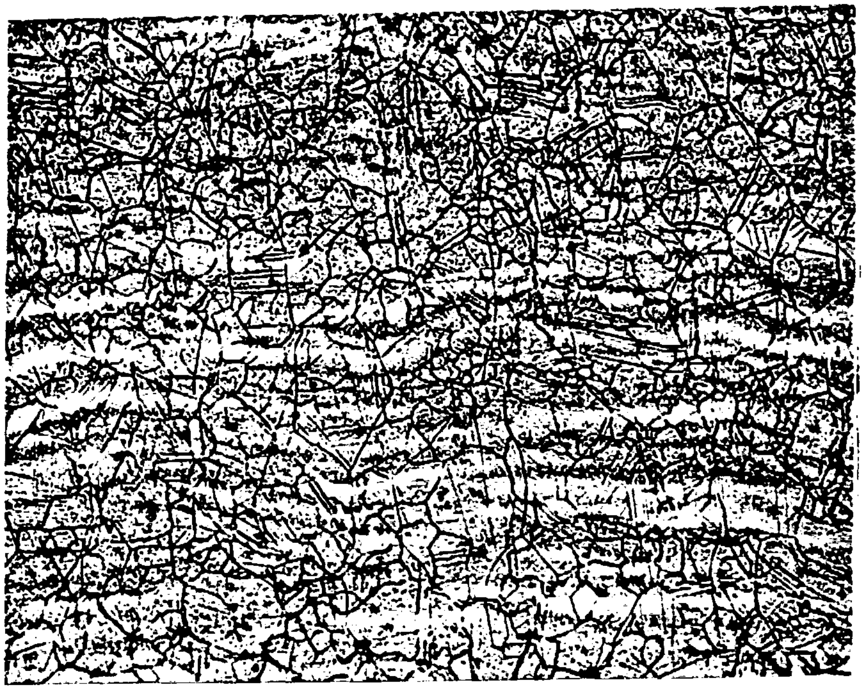


Figure 4-4-5 Metallographic cross section taken from area A (Figure 2) of the flow formed combustor case after being exposed to an AMI 915 braze cycle. Grain size is ASTM No. 5.5. Mt. No. 90-582, Mag: 100X, Etchant: Electrolytic, 10% Oxalic Acid

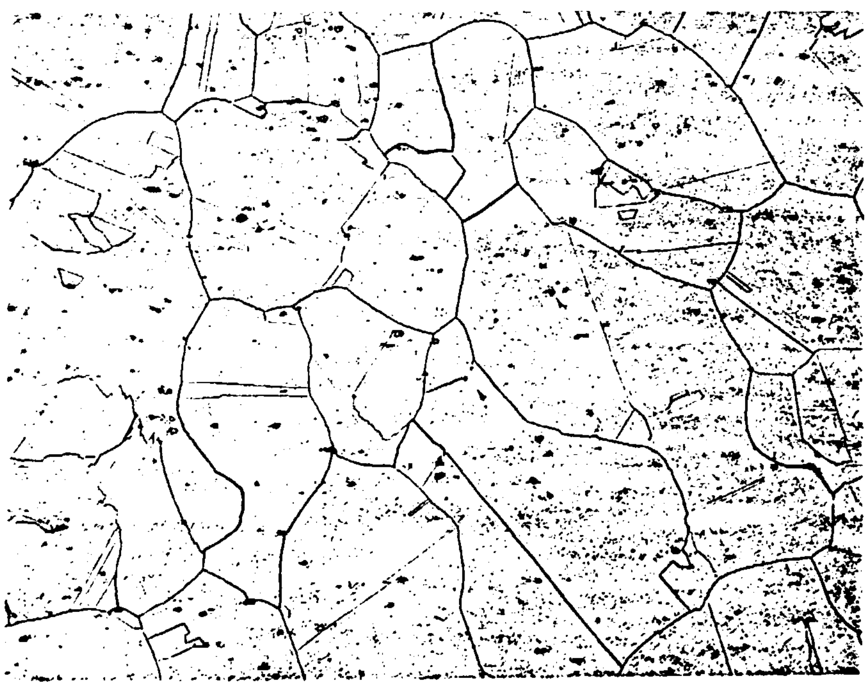


Figure 4-4-6 Metallographic cross section taken from area B (Figure 2) of the flow formed combustor case after being exposed to an AMI 915 braze cycle. Grain size is ASTM No. 1.5. Mt. No. 90-583, Mag: 100X, Etchant: Electrolytic, 10% Oxalic Acid

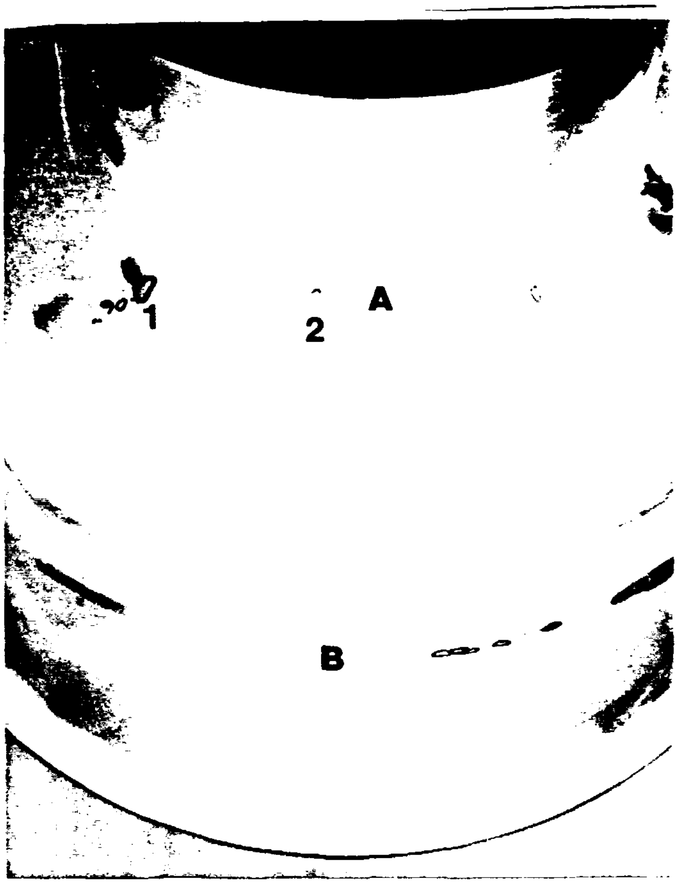



Figure 4-4-7 Overall view of combustor case documenting the location of the penetrant indications. Indications were located either in the radius (Area A) or in a 0.5" band (Area B). Mag: 0.67x

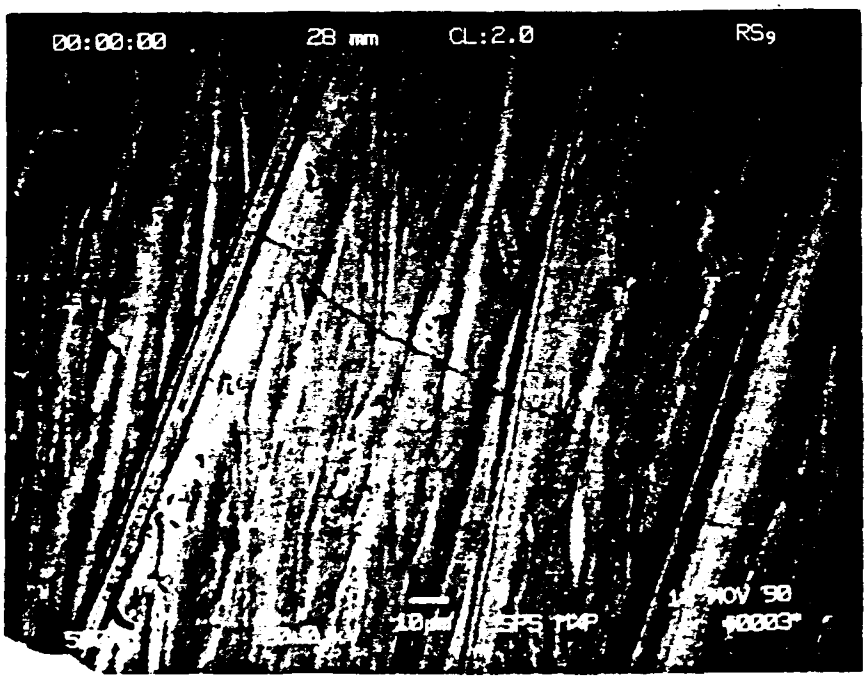



Figure 4-4-8 SEM photograph documenting the crack A1, Figure 7. This crack was parallel to the axis of the combustor case. Mag: 500x


Figure 4-4-9 SEM photograph documenting the crack A2, Figure 7, which was broken open for SEM examination. The depth of the crack was .008" and the length was .005" (arrows). Mag: 40x

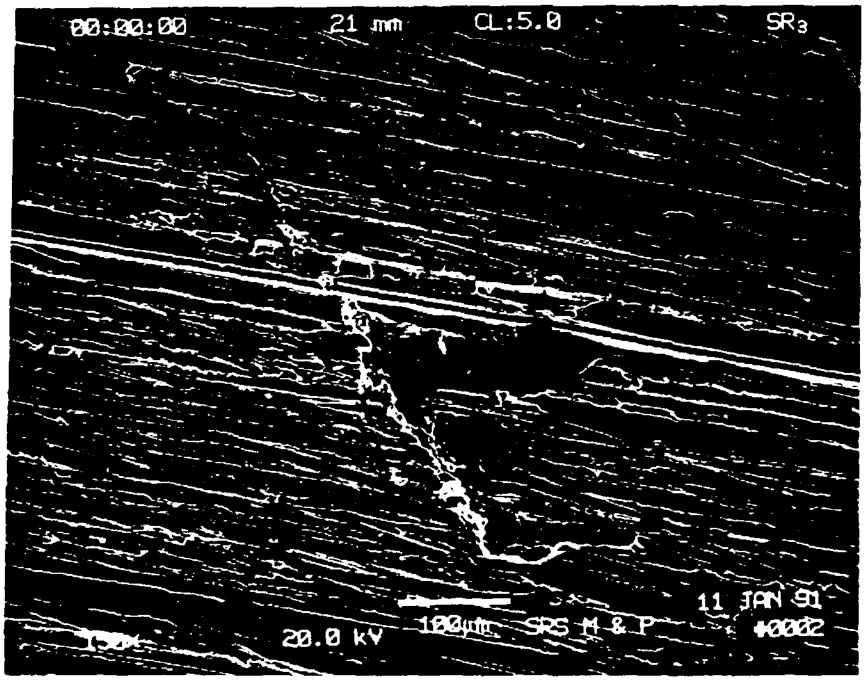



Figure 4-4-10 SEM photograph documenting a typical indication (arrows) in Area B of Figure 7. Mag: 150x

Figure 4-4-11 Metallographic cross section of the indication in Figure 10 verifying that the indication was a lap. The depth of this lap was .005". Mt. No. 91-610, Mag: 200x.

TABLE I. TENSILE RESULTS FOR THE FLOW FORMED COMBUSTOR CASE

| Location | Specimen I.D. (Fig. 2) | Yield Str. (0.2%, ksi) | Tensile Str. (ksi) | Elongation (% in 4D) |
|---|---|---|---|---|
| 11" I.D. | 3A | 48.1 | 103.6 | 32.0 |
| | 3B | 48.0 | 105.3 | 41.0 |
| | 3E | 46.2 | 108.0 | 42.0 |
| 11"I.D. to 6.6" I.D. | 3C | 50.4 | 115.8 | 41.0 |
| Transition | 3D | 55.6 | 110.8 | 44.0 |
| AMS 5536 Minimum Requirements | | 45.0 | 105.0 | 35.0 |

TABLE II. STRESS RUPTURE RESULTS FOR THE FLOW FORMED COMBUSTOR CASE

| Location | Specimen I.D. (Fig. 2) | Test Temp. (F) | Stress (ksi) | Hrs. to Fracture | Elongation (% in 4D) |
|---|---|---|---|---|---|
| 11" I.D. | 4A | 1500 | 22.0 | 43.7 | 59.0 |
| | 4B | 1500 | 20.0 | 44.6 | 35.0 |
| 11"I.D. to 6.6" I.D. | 4C | 1500 | 18.0 | 44.5 | 105.0 |
| Transition | 4D | 1500 | 20.0 | 45.6 | 86.0 |
| AMS 5536 Minimum Requirements | | 1500 | 16.0 | 24.0 | 8.0 |

## 4.5 TEST VALIDATION/QUALIFICATION

The qualification of the flow formed combustor assembly for the T-62T-40LC-2 APU is hereafter referred to as "the unit". The new unit developed under the IMIP project is nearly identical to the current configuration and is interchangeable, but a qualification test was necessary due to the slight differences in shape, metal thickness (one piece design), and material properties. The new unit is expected to be superior as a result of the one piece construction, controlled metal thickness, and fewer number of parts. The unit was tested in conjunction with qualification test of the APU. See Figure 4-5-1, showing the combustor housing installed.

### 4.5.1 TEST REQUIREMENTS

This test will qualify the Turbine Wheel, Nozzle, Containment Ring Extension, and the Combustor Housing.

#### 4.5.1.1 TEST FACILITY REQUIREMENTS

##### 4.5.1.1.1 FUEL

Fuel used during the Qualification Test shall be JP-4. Samples verifying the specific gravity shall be recorded during the 500 start inspection intervals.

##### 4.5.1.1.2 OIL

Oil conforming to MIL-L-7808 shall be used throughout the test. The oil shall be changed during each 500 start inspection interval.

##### 4.5.1.1.3 STARTING

APU starting shall be accomplished using a hydraulic start cart P/N PC75763 designed to simulate the aircraft hydraulic start system.

##### 4.5.1.1.4 LOAD ABSORPTION

The facility bleed ducting shall include a 2-1/2 inch valve, downstream of the customer valve, which will be in the full open position to create a fixed bleed system back pressure. A water dynamometer will be used to apply shaft loading.

##### 4.5.1.1.5 APU INSTALLATION

The APU will be tested in one of the Development Test Facilities located at 4400 Ruffin Road, San Diego, CA. Mounting on the test stand shall be accomplished using facility mounts, which attach to the APU gearbox, and a single support of the powerhead at the six (6) o'clock position.

The APU exhaust shall be directed through the facility exhaust ducting.

The fuel pressure from the facility system shall be regulated to maintain an APU fuel pump inlet pressure of 5 psig to 40 psig.

The APU oil will be directed through a facility oil cooler utilizing the "TO COOLER" and the "FROM COOLER" ports on the gearbox.

The APU will be tested with the inlet air muff installed. Prevailing test cell environment air will be drawn into the muff and consumed at approximately three hundred six (306) ppm.

Facility shop air at 70 psig and 90 psig will be ducted into the APU/facility exhaust ducting in accordance with the Test Duty Cycle. This air is intended to reduce the turbine wheel bulk temperature to simulate a cold start for each cycle.

A Systems and Controls Engineering/facility load cycle controller will provide for automated start and run operation for Cycles A and B. This load cycle also controls the shop air ON and OFF. An interlock function is programmed into the load cycle to prevent APU restarting until a complete thermal cycle is completed.

Load absorption shall be accomplished by directing the load compressor discharge air via facility ducting through a customer start control valve. Bleed and bypass operation will be controlled by the ESCU.

### 4.5.1.2 TEST DUTY CYCLES

The Qualification Test shall consist of the following cycles:

CYCLE A Start and run for two (2) minutes at 1200 °F EGT NORMAL MODE. Add a 20 HP shaft load and run for twenty-five minutes in GEN ONLY MODE. Remove shaft load and continue running to GEN ONLY MODE for eighteen (18) minutes.

Stop and wait until EGT is ≤ 300 °F (AIR OFF). Turn air on until EGT is ≤ 100 °F.

CYCLE B Start and run for fifteen (15) minutes NORMAL MODE.

Stop and wait until EGT is ≤ 300 °F (AIR OFF). Turn air on until EGT is ≤100 °F.

CYCLE C Start and run in EWO (1300°F EGT) for forty-five (45) minutes.

Stop and wait until EGT is ≤300 °F (AIR OFF). Turn air on until EGT is ≤100 °F.

A graphic display of the above cycles is shown in Figure 4-5-2.

Currently, we are required to provide the following service life per the BMA SOCD 458-50065:

| | |
|---|---|
| HOURS | 1010 |
| EWO | 25 |
| STARTS | 750 |

This qualification test plan will demonstrate:

| | |
|---|---|
| HOURS | 1035 |
| EWO | 27 |
| STARTS | 2052 |

The APU hourmeter and event (start) counter shall be used to document the starts and operating hours during this qualification test.

Cycles A and B will be controlled by an automatic load cycler. Cycle C will be controlled manually.

4.5.1.2.1 ENGINE INSPECTION

Periodic inspections will be performed at approximately 250 start intervals. The inspections will include visual inspection of each part being qualified.

4.5.1.2.2 CONDITIONS REQUIRING SHUTDOWN

The mandatory limits are those limits which would normally cause the engine to shut down on its own protective circuits. Operation in excess of these limits shall be cause for immediate shutdown of the test unit and determination of the cause for failure of the automatic shutdown.

The discretionary limits are those limits which rely on the observation of the Test Operator to initiate an engine shutdown should the engine operation exceed any of the specified limits. The Test Operator shall shut down the unit unless the Test Engineer is available for immediate consultation. These limits may be exceeded at the instruction of the Test Engineer within the limits of reasonable engineering practice.

The following are the limits of operation to be observed during all phases of testing:

a) Evidence of fuel or air leak.

b) Abnormal noise, smoking, or exhaust flame.

c) Vibration in excess of 5 Gs at rotor frequency when operating under pneumatic load and/or shaft load. Vibration in excess of 10 Gs at rotor frequency when operating under no pneumatic load (IGV's closed) nor shaft load.

d)* Oil pressure below 18 psig at 100 percent speed.

e)* Oil sump temperature exceeds 275 °F.

f) Surge at any time during operation or acceleration.

g) Exhaust gas temperature that exceeds 1320 °F for more than 10 seconds.

h) Measurable oil consumption exceeds 20 cc/Hr as measured at the reduction gearbox oil vent.

i) Speed variation at constant load exceeds 0.5 percent. Speed variation during on/off load transient exceeds 2 percent.

* Mandatory shutdown

### 4.5.1.3 INSTRUMENTATION

All instrumentation shall be inspected and certified to be within calibration. Development Test Engineering shall be responsible for meeting these requirements. The data requirements intervals are listed in Table I.

## 4.5.2 TEST RESULTS

The combustor housing assembly of the new proposed design and configuration underwent all test conditions without any indication of any material or design weaknesses. Testing validated the design and analyses covered in Sections 3.0, 4.0, and 5.0 of this report.

Duty cycles were run continuously 24 hours per day. Occasional interruptions were made for inspection, troubleshooting, and facility maintenance. The test duty cycle involved three different operating cycles separated by identical cool down cycles, reference Section 4.5.1.2. One C (EWO) cycle was run for every 28 A and B cycles (one C cycle for each 57 total cycles). The A and B cycles were executed automatically through the use of a "load cycler box". After the EGT cooled to 100 °F, the cooling air was automatically turned off and the load cycler initiated another start. The C cycles were run at convenient times and were initiated manually but runs automatically once initiated.

A summary of significant events is shown in Figure 4-5-3.

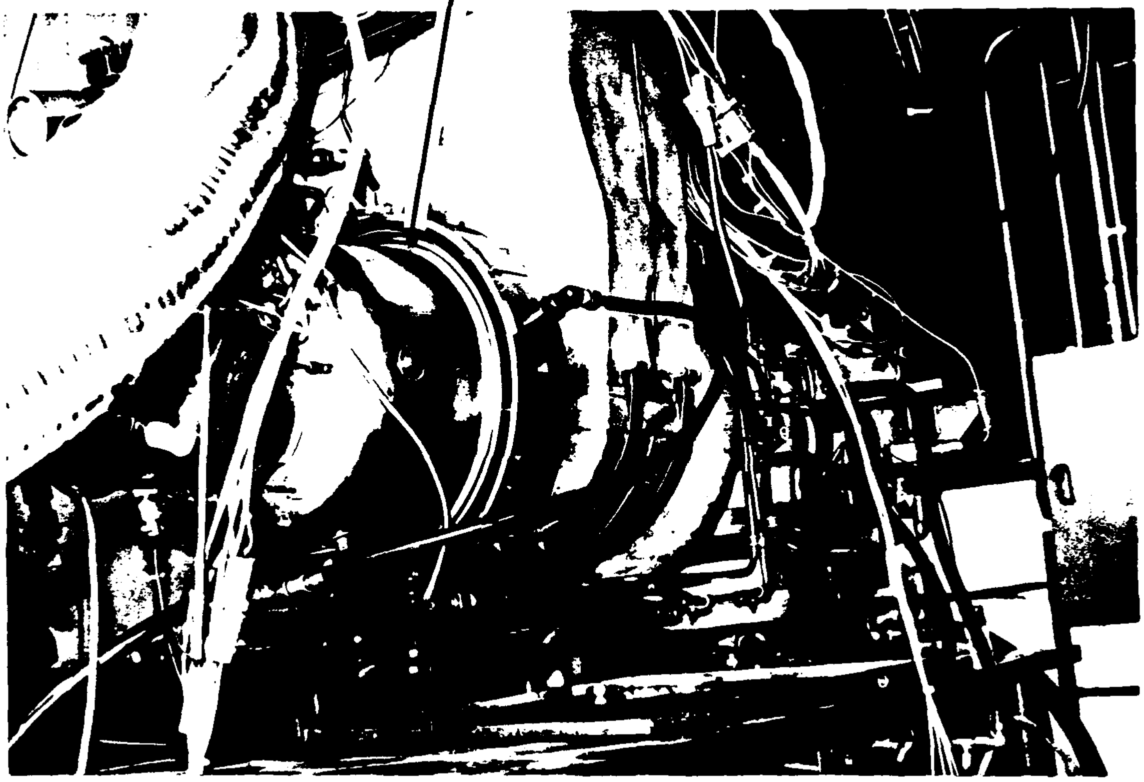



Figure 4-5-1 Test Set-up

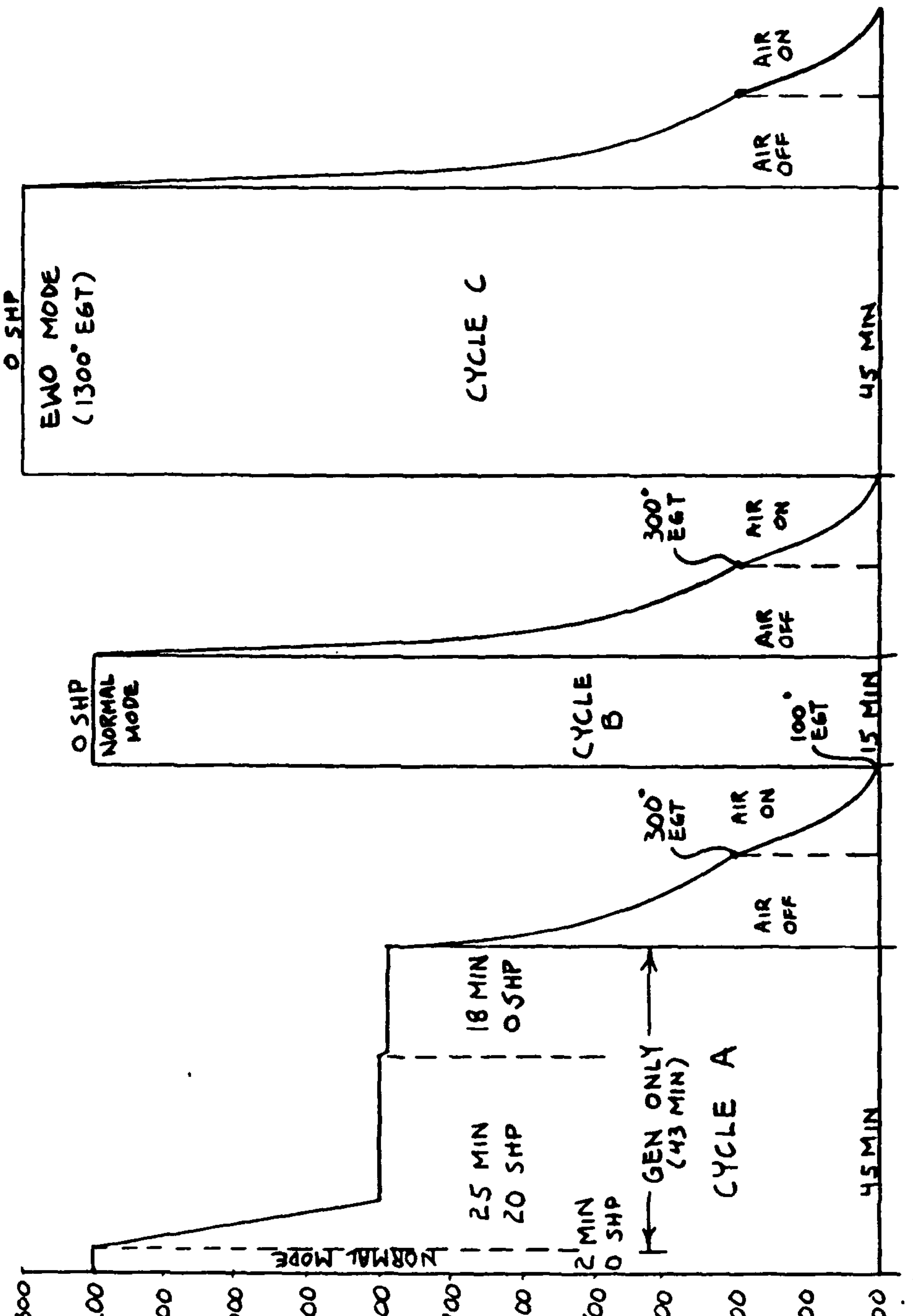



Figure 4-5-2 Test Duty Cycles

KC-135R IR&D ENDURANCE TESTS
SIGNIFICANT EVENT SUMMARY

| DATE | EVENT | CYCLE | HOURS | EVENTS |
|---|---|---|---|---|
| 01/24/91 | START COATED TURBINE WHEEL TEST ON APU 850568 | 0 | 0.0 | 0 |
| 02/06/91 | REMOVE APU 850568 (NOTE: ENGINE USING 200-300 CC/HR OIL) | 275 | 144.1 | 327 |
| 02/07/91 | INSTALL APU 001 W/ BORELESS TURBINE WHEEL | 0 | 0.0 | 0 |
| 02/08/91 | HYDRAULIC STARTER SHAFT SHEARED APU 001 | 3 | 1.0 | 5 |
| 02/13/91 | REMOVED APU 001 DUE TO HIGH VIBES | 122 | 59.8 | 125 |
| 02/21/91 | INSTALL COATED TURBINE WHEEL APU 850568 | 275 | 144.1 | 327 |
| 02/27/91 | INSTALLED NEW PURGE ORIFICE AND START NOZZLE | 431 | 223.7 | 501 |
| 03/04/91 | REMOVE APU 850568 | 514 | 226.5 | 585 |
| 03/05/91 | INSTALL APU 001 W/ RESTRETCHED TIEBOLT, | 122 | 59.8 | 125 |
| 03/16/91 | END OF BORELESS T/W TEST APU 001 (201 A, 209 B, 7 C CYCLES) | 417 | 208.9 | 434 |

Note: A SINGLE HAST-X COMBUSTOR WAS USED FOR TESTING ON BOTH ENGINES AND ACCUMULATED A COMBINED RUNTIME OF 435.4 HRS/1019 EVENTS

Figure 4-5-3 Summary Of Significant Test Events

# 5.0 LASER TECHNOLOGY

## 5.1 TECHNICAL APPROACH

Current combustor housings are brazed assemblies which require about 10 hours/ combustor to assemble. A flow formed combustor minimizes labor by reducing the number of components and is estimated to require 5.2 hours per combustor. Labor required to assemble a combustor would be reduced even further by laser welding which is estimated to require 2.3 hours per combustor.

Before laser welding can be considered for combustor applications specific process parameters have to be developed and evaluated. The laser weld joints must be as strong in shear as the .040 inch Hastelloy X base metal in tension and have a fatigue life comparable to the current brazed joint design.

## 5.2 LASER WELD PARAMETERS AND JOINT DESIGN

5..2.1 Tensile Test Procedure

Panels were assembled in a joint design which simulates a boss welded to the combustor case (Figure 5-14) and a diffuser welded to the combustor case (Figure 5-15). To evaluate the effects of weld types, fusion zone width, and gap width on the weld joint design, panels were welded together using two weld types, two fusion zone widths (.040 inch and .080 inch), and two gap widths (.006 inch and .010 inch). Tensile specimens were machined from these panels and tested per ASTM E8 (Figure 5-1).

The variables evaluated by the tensile testing were:

Weld Joint Design: Three piece lap joint using Hastelloy X and 347 CRES.
Two piece lap joint using Hastelloy X to Hastelloy X.

Weld Types: 90 Degree Fillet (Figures 5-16 and 5-17)
Seam Weld (Figures 5-18 and 5-19)

Fusion Zone Width: 1 or 2 times the base metal thickness (.040 inch or .080 inch)

Gap Width: .006 inch and .010 inch

A Trump 1500 Watt CO 2 laser was selected for the test program. This laser simulates the type of laser which would be purchased through the IMIP program. The fusion zone widths to be evaluated were one and two times the base metal thickness (.040 inch and .080 inch). Linear welds were made on panels of Hastelloy X to Hastelloy X and Hastelloy X to 347 CRES using various laser settings. The laser parameters which resulted in a .040 inch fusion zone at the interface of the .040 inch panels were:

Power: 1500 Watts

Focal Length: 3.75 inches

Focus: 1/3 down from maximum height

Backup gas: Helium, 85 psi both sides

Travel Speed: 40 inches per minute

Pulse Setting: Continuous Wave, 95% Power, 5 khz

To achieve a fusion zone width of .080 inch two passes .040 inch apart were used.

### 5.2.2 TENSILE RESULTS

Results of room temperature tests appear in Table I. All of the fractures occurred outside the weld. The three piece joint design typically failed just outside the heat affected zone while the two piece joint design typically failed away from the weld (Figure 5-1).

### 5.2.3 HIGH CYCLE FATIGUE (HCF) TEST PROCEDURE

Panels for HCF testing of the two piece lap joint design were identical to the tensile panels (Figure 5-15). The panels for the HCF testing of the three piece lap joint were modified by reducing the 347 CRES strip from 1.5 inches to 0.75 inch to fit within the gauge section and adding a laser weld in the centei (Figure 5-20).

One weld type, a 45 degree fillet, was added to the HCF testing. In the 45 degree fillet weld (Figure 5-21) the weld beam impacts the base metal at a 40 degree angle vs. a 90 degree angle for the seam and 90 degree fillet welds (Figures 5-16 and 5-18). The fusion zone width was held constant at .040 inch, and the gap widths were .006 inch and .010 inch.

The variables evaluated by the HCF testing were:

Weld Joint Design: Three piece lap joint using Hastelloy X and 347 CRES.
Two piece lap joint using Hastelloy X to Hastelloy X.

Weld Types: 45 Degree Fillet (Figure 5-20)
90 Degree Fillet (Figures 5-16 and 5-17)
Seam Weld (Figures 5-18 and 5-19)

Fusion Zone Width: .040 inch

Gap Width: .006 inch and .010 inch

HCF specimens were machined from these welded panels and tested (Figure 5-10). The test parameters were:

Specimen Type: Cantilever Bend

Mode: Full reversal

Temperature: Ambient

R Ratio: -1

Frequency: 30 Hz

Cycles to Failure: $5 \times 10^5 - 10^7$

### 5.2.4 HCF RESULTS

The results appear in Figures 5-7, 5-8, 5-22, 5-23, and Tables II and III.

Three Piece Lap Joint, .006 inch Gap Width: The 45 degree fillet welds had the best HCF properties (Figure 5-7). The 45 degree fillet weld had a concave fillet vs. the 90 degree fillet welds which had a convex weld (Figures 5-16 and 5-21). The concave fillet was more effective at minimizing the stress concentration at the weld than the convex fillet.

Two Piece Lab Joint, .006 inch Gap Width: There was no difference in the HCF properties between the 90 degree fillet weld and the seam weld (Figure 5-8). The 90 degree fillet weld was expected to have better HCF properties because the fillet would minimize the stress concentration, but this was not the case.

Three Piece Lap Joint, .010 inch Gap Width: There was no significant difference between the fatigue strength of the 45 degree fillet weld and the 90 degree fillet weld (Figure 5-22). The fatigue strength of the .010 inch gap width 90 degree fillet weld specimens increased compared to the .006 inch gap width specimens (Figures 5-7 and 5-22).

Two Piece Lap Joint, .010 inch Gap Width: The 90 degree fillet weld specimens had a higher fatigue strength than the seam weld specimens (33 ksi vs. 23 ksi at 10 to the 6th. cycles, Figure 5-23). The gap width has a minimal affect on the fatigue strength of the 90 degree fillet weld specimens (32 vs. 32 ksi fatigue strength at 10 to the 6th. cycles, Figures 5-8 and 5-23). However, the .010 inch gap width resulted in a 30% reduction in fatigue life for the seam weld specimens (33 vs. 23 ksi fatigue strength at 10 to the 6th. cycles, Figures 5-8 and 5-23).

## 5.3 EFFECTS OF RECAST LAYER ON HIGH CYCLE FATIGUE

One aspect of IMIP is to reduce cost by the use of laser technology in the fabrication of sheet metal components. Laser trimming and cutting are two ways to reduce cost.

The main concern is that the recast layer may have an adverse effect on high cycle fatigue (HCF) life. The current practice for laser machined combustor cases is to allow .002 inch max. recast layer with no microcracks. The following evaluation was initiated to quantify the effects of the depth of recast layer on HCF properties of laser machined sheet metal components.

### 5.3.1 PROCEDURE

In order to establish the laser parameters, single cuts were made in Hastelloy X sheets varying the travel speed, flow through gas pressure, and wave mode. A 1000 Watt Mazak Laser was used in this study.

To achieve .006 inch of recast layer both travel speed and flow through gas pressure had to be reduced. After numerous attempts it was decided to keep the travel speed and mode constant, and modify the back-up gas pressure to achieve the various depths of recast layer.

The laser parameters were:

Power: 1050 Watts

Travel Speed: 1 inch per minute

Pulse Setting: Continuous wave

Back-up Gas Pressure:
30 psi - .006 inch recast layer
60 psi - .004 inch recast layer
120 psi - .0025 inch recast layer
160 psi - .001 inch recast layer

To minimize material variation effects, all of the HCF specimens were machined from the same sheet of Hastelloy X. The specimen geometry is shown in Figure 5-25.

The depth of recast layer was not consistent along the length of the gauge region (Figure 5-25). One of the reasons that cantilever bending HCF specimens were selected was to maximize the area of constant stress (the entire gauge region is under constant stress) thus minimizing the effects of the recast layer being inconsistent. Cantilever bending HCF specimens are also the best specimen geometry for simulating the loading of the combustor case.

The specimens were deburred. Another batch of specimens were machined on an end mill and tested as a baseline without being polished.

The test parameters were:

Specimen Type: Cantilever Bend

Mode: Full reversal

Temperature: Ambient

R Ratio: -1

Frequency: 30 Hz

Cycles to Failure: $5 \times 10^5 - 10^7$

## 5.3.2 Results

The results appear in Figures 5-11, 5-26, 5-27, and Table IV. There was a direct relationship between the depth of recast layer and the endurance limit. Based on limited data, the difference in the endurance limit between a machined surface and .0025 inch thick recast layer is 8 ksi or 20% reduction in the endurance limit (38 ksi vs. 30 ksi, Figures 5-9 and 5-10). The difference between a .0025 inch recast layer and .006 inch was minimal (Figures 5-10 and 5-11).

A metallographic examination of the gauge section of one HCF specimen representing each depth of recast layer revealed that there were no microcracks, even in the specimens with .006 inch of recast layer. There was evidence of carbide precipitation at the grain boundaries adjacent to the recast layer (Figure 5-12).

## 5.4 HIGH CYCLE FATIGUE PROPERTIES OF AMS 4777 AND AMI 915 BRAZE JOINTS

The current combustors are brazed assemblies. Two nickel base braze alloys used at Sundstrand Power Systems are AMS 4777 and AMI 915. Some combustors have failed in the field because a high cycle fatigue crack has originated in the braze fillet. Determining which braze alloy has the best HCF properties is key to improving the life of combustors.

The AMS 4777 alloy will be evaluated in the as-brazed condition and the AMI 915 alloy will be evaluated in the as-brazed condition and also after a diffusion heat treatment. The diffusion heat treatment would improve toughness which may improve HCF properties. The diffusion heat treatment may also be weld repairable which would reduce combustor housing repair costs.

### 5.4.1 PROCEDURE

Panels of .040 inches thick Hastelloy X were resistance spot welded to a 0.75 inches strip of 347 CRES to simulate a boss being brazed to the Hastelloy X combustor case (Figure 5-20). The material was from the same sheet of Hastelloy X cut perpendicular to the grain flow. These panels were brazed using the AMS 4777 and AMI 915 braze alloys. HCF specimens were machined from these panels and tested.

The test parameters were:

Specimen Type: Cantilever Band

Mode: Full reversal

Temperature: Ambient

R Ratio: -1

Frequency: 30 Hz

Cycle to Failure: $5 \times 10^{5} - 10^{7}$

### 5.4.2 RESULTS

Results appear in Figure 5-7 and Table V. Most of the fatigue origins were adjacent to the braze fillet (Figure 5-2). The endurance limit of the brazed specimens varied from 36 ksi for the AMS 4777 specimens (Figure 5-5) to 33 ksi for the AMI 915 specimens (Figures 5-6 and 5-7). The lower fatigue limit of the AMI 915 specimens is the result of grain growth in the base metal due to the higher brazing temperatures (Figures 5-28 and 5-29).

## 5.5 EFFECTS OF BRAZING TEMPERATURES ON 347 CRES

The *current braze* alloy, AMI 915, requires a brazing temperature of 2100°F or 50°F above the maximum recommended annealing temperature of 347 CRES (1800-2050°F). These temperatures may affect performance by causing grain growth and reducing tensile strength, especially in thin (.040 inches) sheet.

The braze cycles selected for evaluation were AMS 4777 and AMI 915. Both of these braze alloys are nickel base and are commonly used in combustor applications. The braze cycle for AMS 4777 is 1950F for 7 minutes and the braze cycle for AMI 915 is 2100F for 9 minutes. The panels will be exposed to each braze cycle twice to simulate a worst base scenario.

The recommended annealing temperature for 347 CRES is 1800-2020°F. Exposing the thin (.040 inches thick) 347 CRES sheet stock to temperatures above 1900F may have an adverse affect on mechanical properties.

### 5.5.1 PROCEDURE

A 36 inches x 6 inches x .040 inches sheet of 347 CRES per AMS 5512 was divided into 3 segments. One segment was tensile tested in the as-received condition, one segment was exposed to two AMS 4777 braze cycles (195°F for 14 min.) and one segment was exposed to two AMI 915 braze cycles (2100°F for 18 min.). Tensile specimens were machined from the panels in the longitudinal and transverse directions and tested per ASTM E8 (Figure 5-30).

Metallographic cross sections were made of the forementioned panels in the longitudinal and transverse directions. *Grain size was measured per ASTM E112.*

### 5.5.2 RESULTS

Results appear in Figure 5-13 and Table VI. The effect of the braze cycle is most noticeable in the yield strength. There was a reduction of 5 ksi in the yield strength between the as-received specimens and the specimens exposed to the AMS 4777 braze cycles. There was a 9 ksi reduction in yield strength between the as-received specimens and the specimens exposed to the AMI 915 braze cycles.

The main effect of the braze cycles on the microstructure of the panels was grain growth. The grain size increased from ASTM No. 10 in the as-received material, to ASTM No. 9 after exposure to the AMS 4777 braze cycles, to ASTM No. 6 after exposure to the AMI 915 braze cycles (Figures 31-33). There is a direct correlation between the reduction in yield strength and the increase in grain size (Figure 5-13 and Table VI).

## 5.6 CONCLUSIONS

A fusion zone width equal to or greater than the base metal thickness results in a weld joint which is stronger than the base metal regardless of the weld joint design, weld type, or gap width (Figure 5-1 and Table I).

The brazed specimens had higher endurance limits than the welded specimens. The endurance limit for the brazed specimens varied from 33-36 ksi compared to 22-26 for the welded specimens (three piece lap joint, .006 inches gap width, Figures 5-2 - 5-7). If the welded specimens are exposed to the AMI 915 braze temperatures (2100F for 9 min.) the endurance limit may be reduced even further by grain growth in the base metal.

For a three piece lap joint with a .006 inch gap width the 45 degree fillet weld has the best HCF properties (Figure 5-7).

For a two piece lap joint with a .006 inch gap width, a seam weld and a 90 degree fillet weld have equivalent HCF properties (Figure 5-8).

Based on limited data, increasing the depth of recast layer from 0.0 (a machined surface) to .0025 inch of recast layer (our current standard is .002 inches) would result in an 8 ksi or 20% reduction in the endurance limit (28 ksi vs. 21 ksi, Figures 5-9 and 5-10). Increasing the depth of recast layer from .0025 inch to .006 inch had a minimal effect on the endurance limit (Figures 5-10 and 5-11).

Laser machining causes carbide precipitation at the grain boundaries adjacent to the recast layer. The effect of carbide precipitation in the grain boundaries of the Hastelloy X would be to reduce elongation by up to 50% and low cycle fatigue strength by up to 25% (ref. Superalloys 1988 Symposium Proceedings). The volume of material affected by the carbide precipitation is small (.012 inch thick layer, Figure 5-12), therefore the overall effect on the low cycle fatigue life of the combustor case is negligible.

The AMS 4777 brazed specimens has a 3 ksi or 8% higher endurance limit than the AMI 915 brazed specimens (36 ksi vs. 33 ksi, Figure 5-7). This was attributed to grain growth due to the higher brazing temperatures o the AMI 915.

The braze cycles caused grain growth which resulted in lower tensile properties for the specimens exposed to the braze temperatures (Figure 5-13).

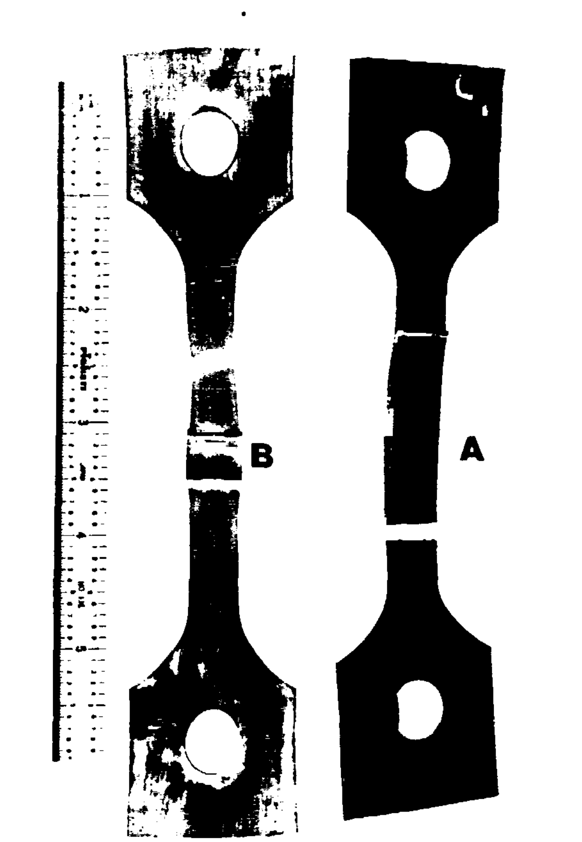



Figure 1. Typical tensile fracture. The fractures occurred adjacent to the weld in the heat affected zone in the three piece joint design (A), and away from the weld in the two piece joint design (B).

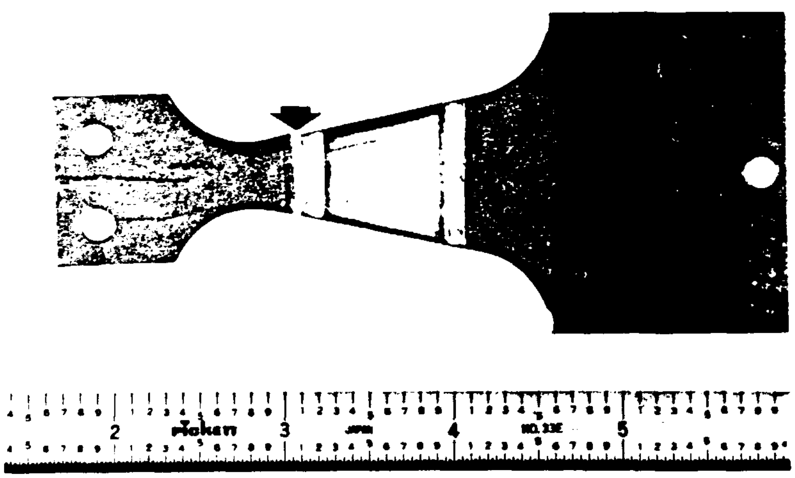


Figure 2. Typical brazed cantilever bending HCF specimen. Failures occurred just outside the braze fillet (arrow).

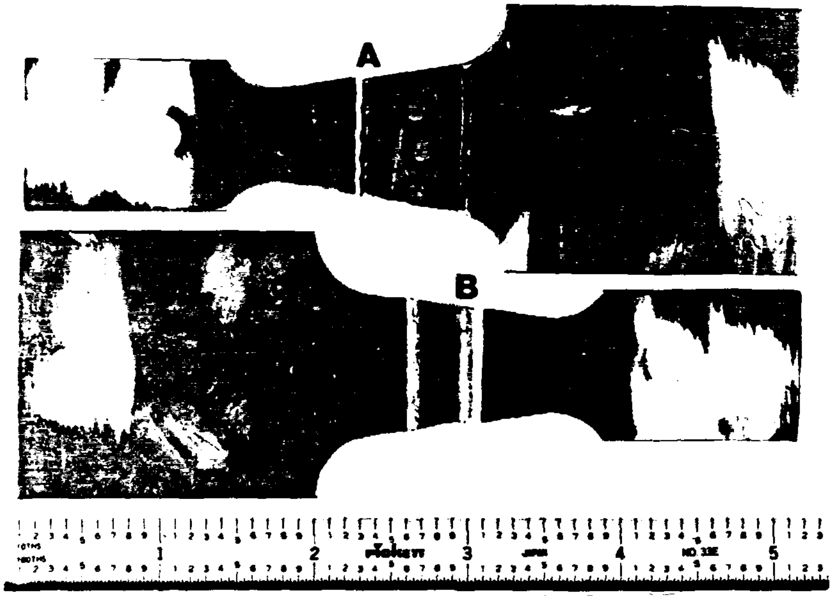



Figure 3. Typical Laser Welded HCF specimens after testing. Specimen A is a three piece joint design (0.75" wide CRES strip) and specimen B is a two piece joint design. The failures occurred just outside the weld in the heat affected zone.

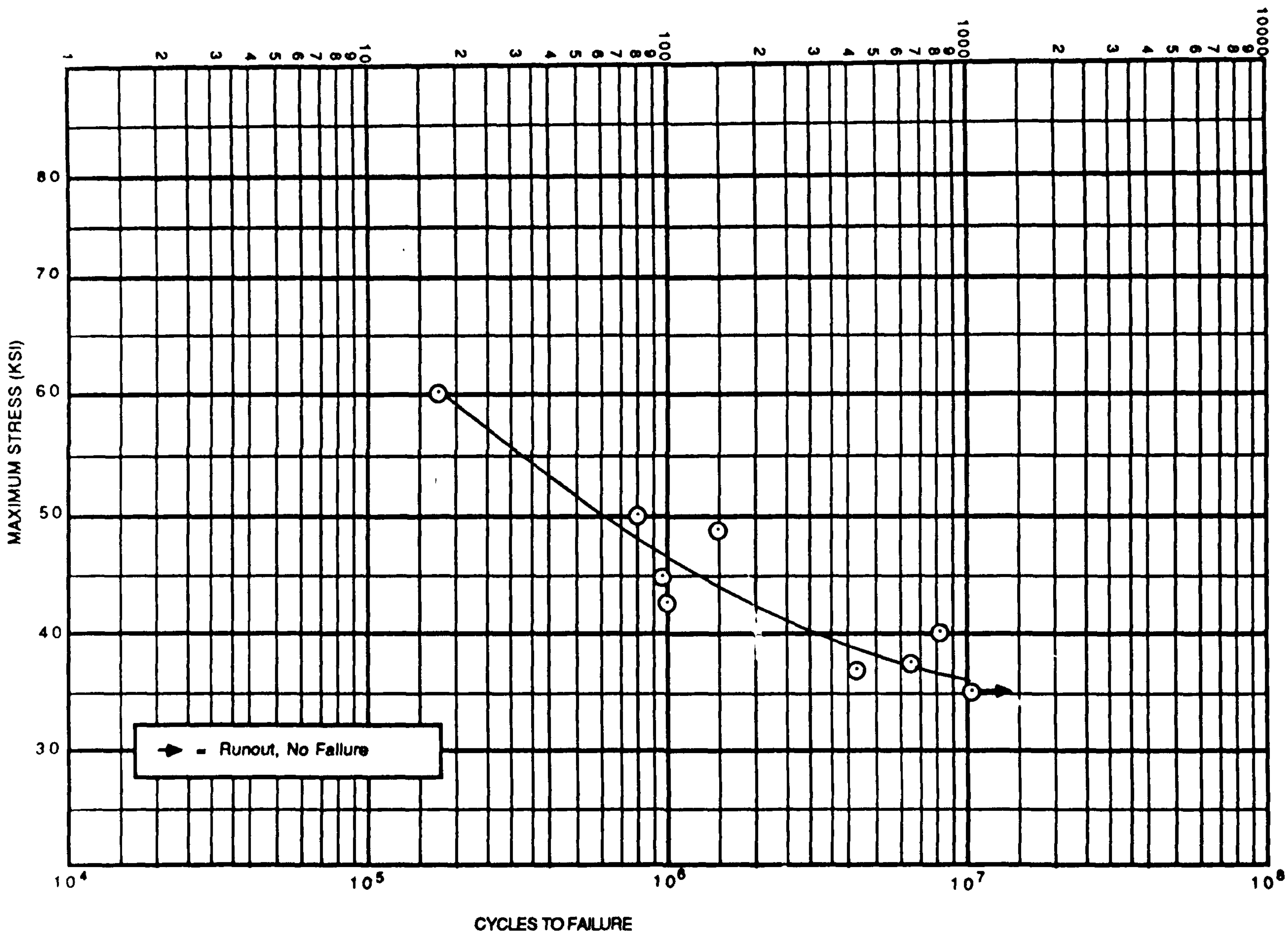



Figure 4. High Cycle Fatigue Results For Specimens Brazed With AMS 4777

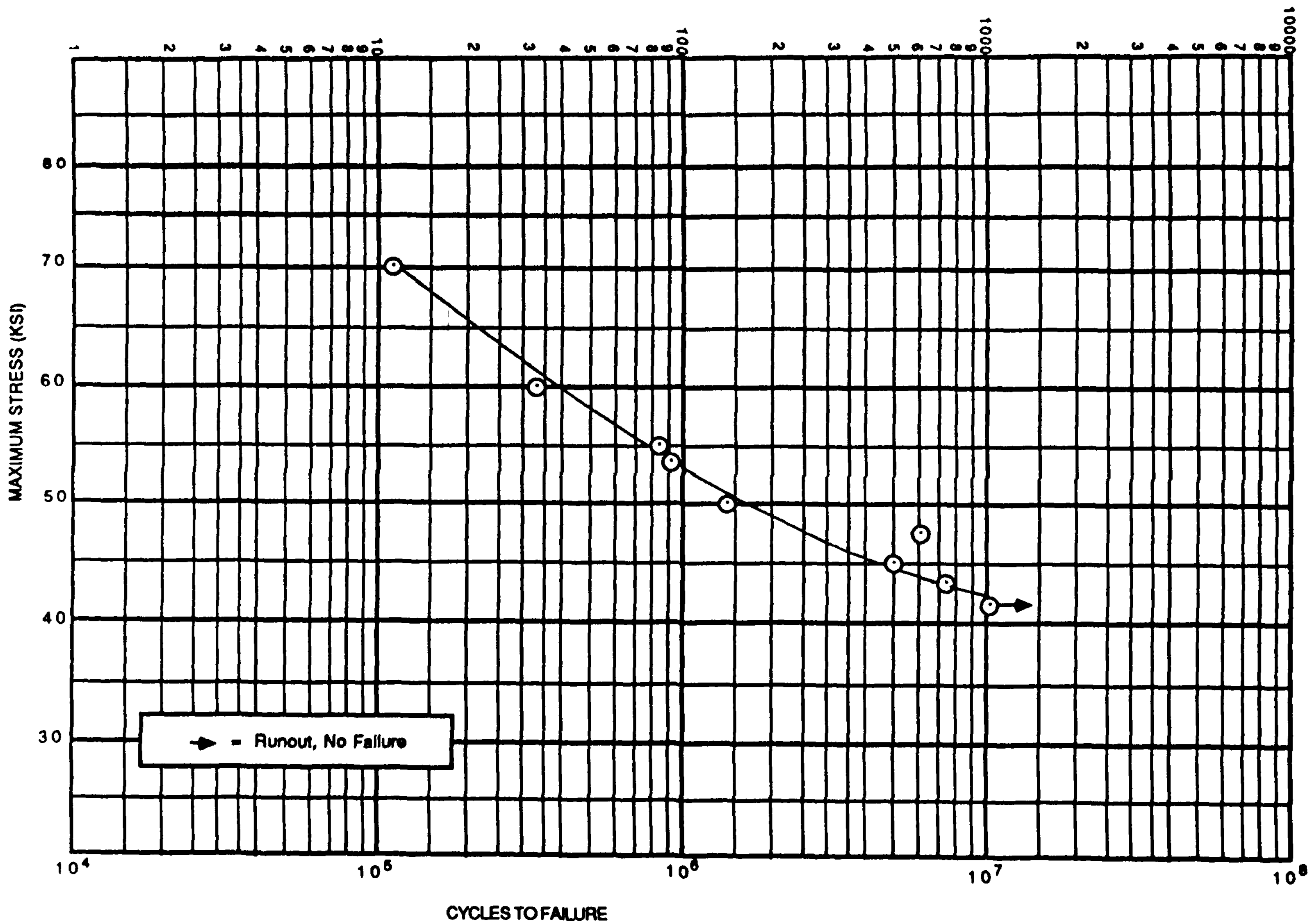



Figure 5, High Cycle Fatigue Results For Specimens Brazed With AMI 915

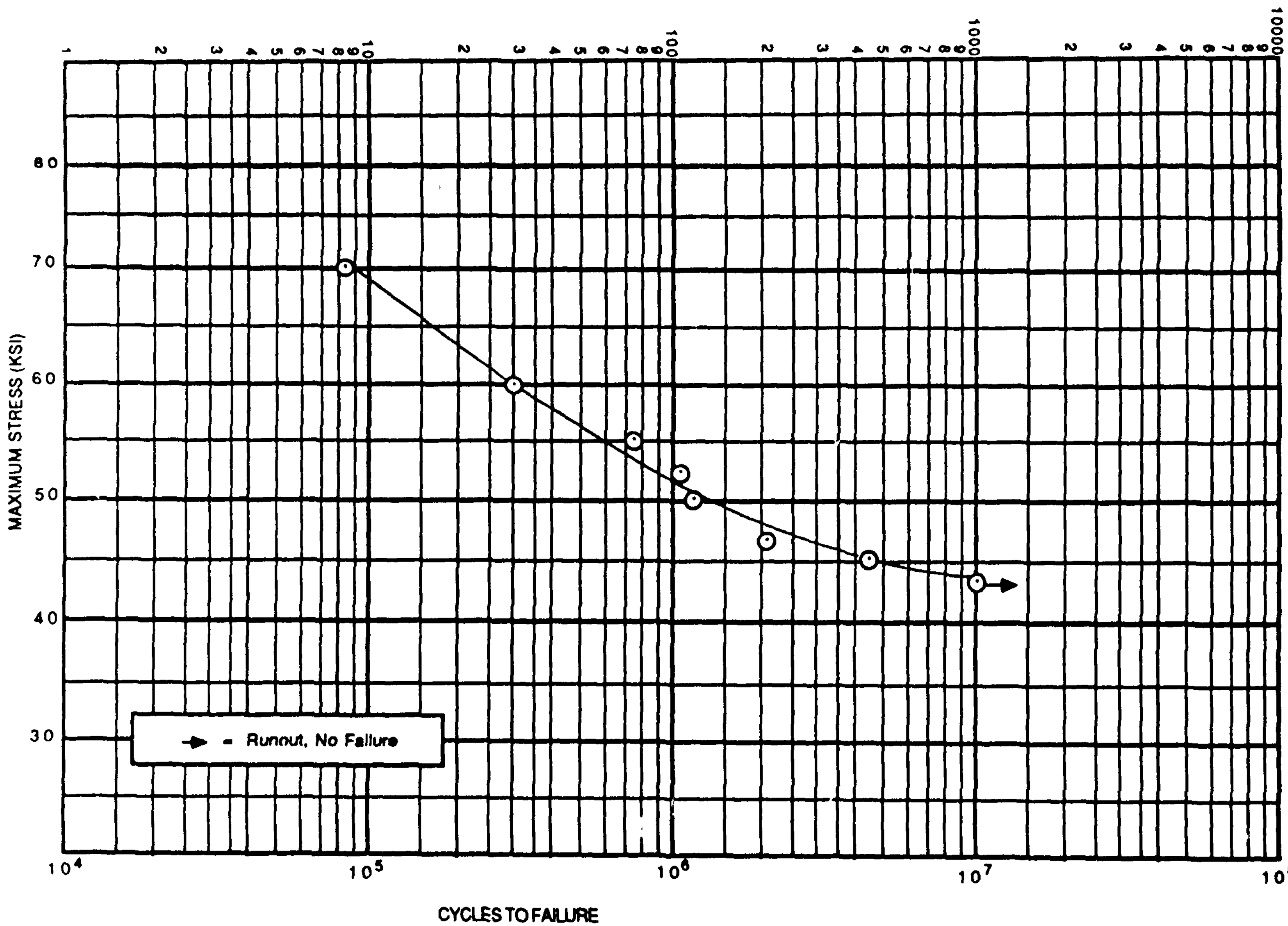



Figure 6. High Cycle Fatigue Results For Specimens Brazed With AMI 915 & Diffusion Heat Treated

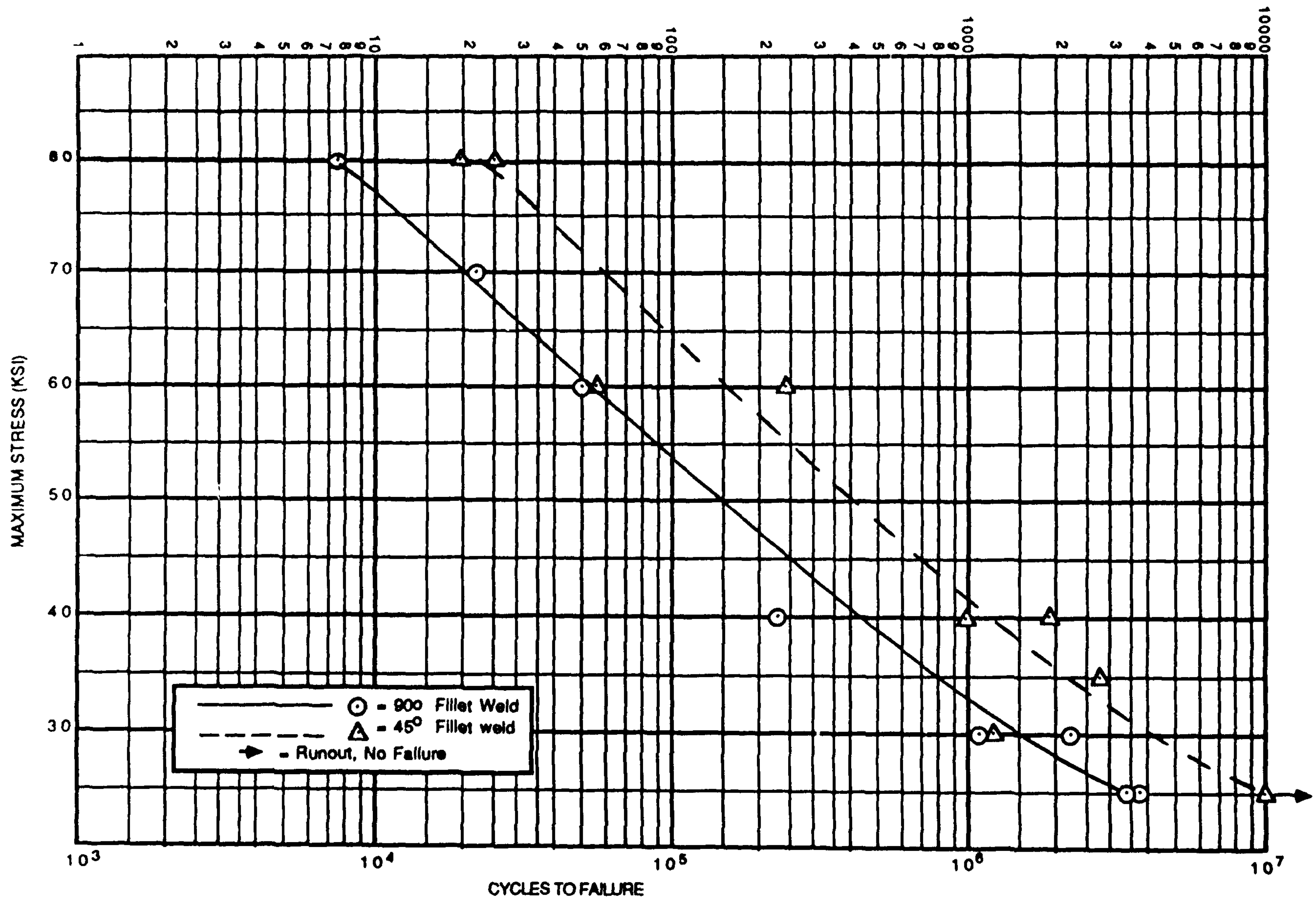



Figure 7. High Cycle Fatigue Results For Laser Welded Three Piece Lap Joint Specimens, .006 Gap Width

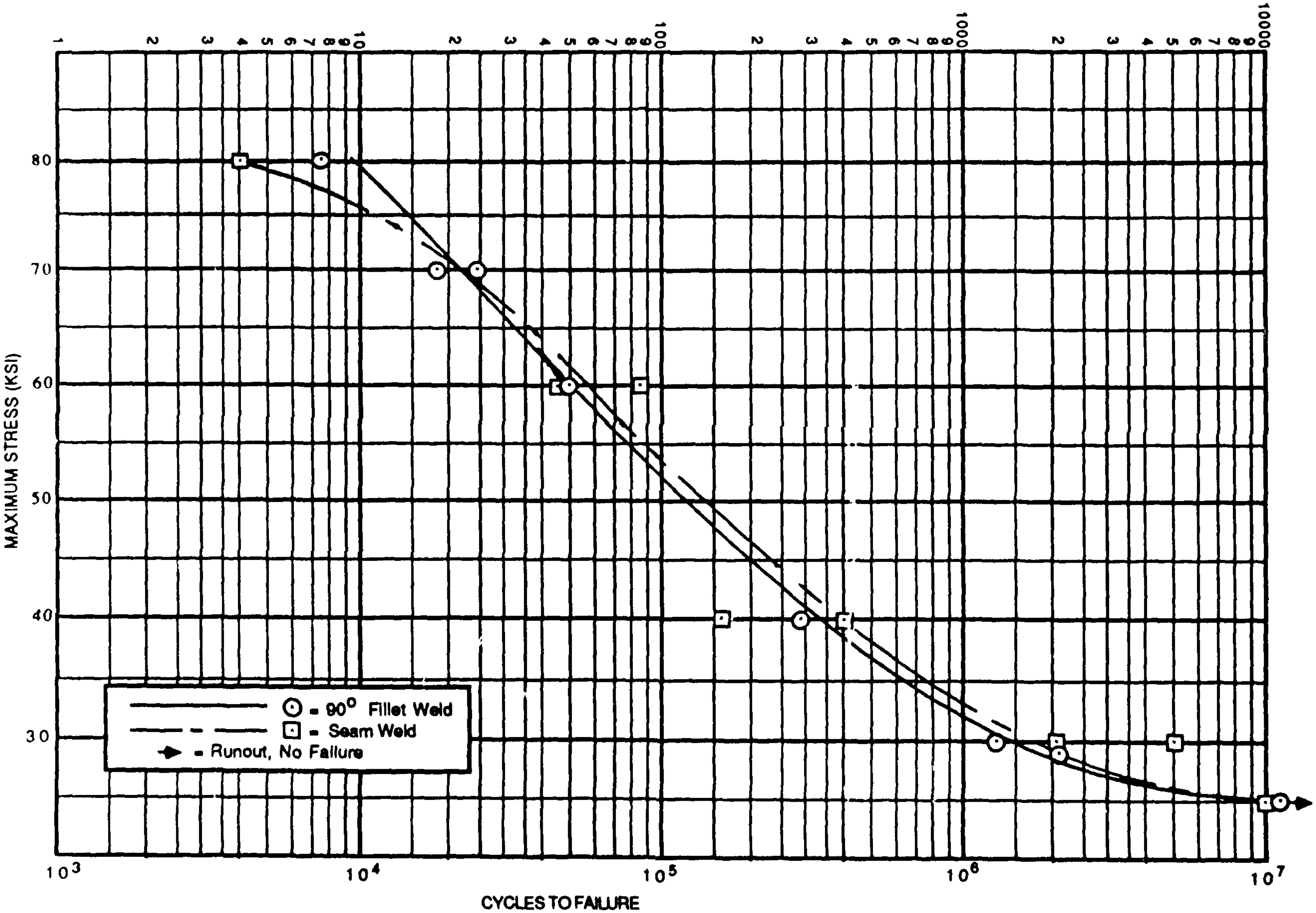



Figure 8. High Cycle Fatigue Results For Laser Welded Two Piece Lap Joint Specimens, .006 Gap Width

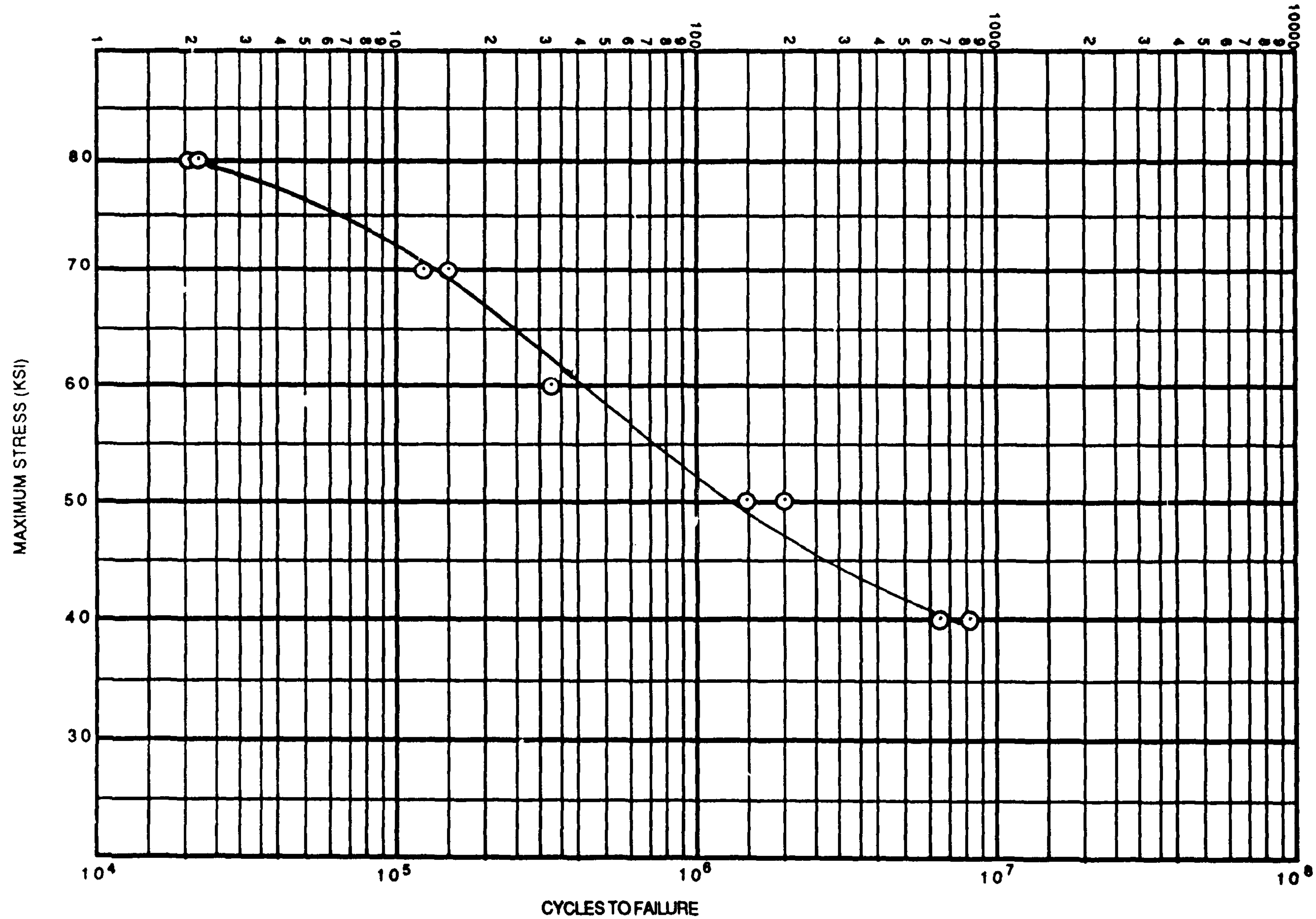



Figure 9. High Cycle Fatigue Results For Machined Specimens

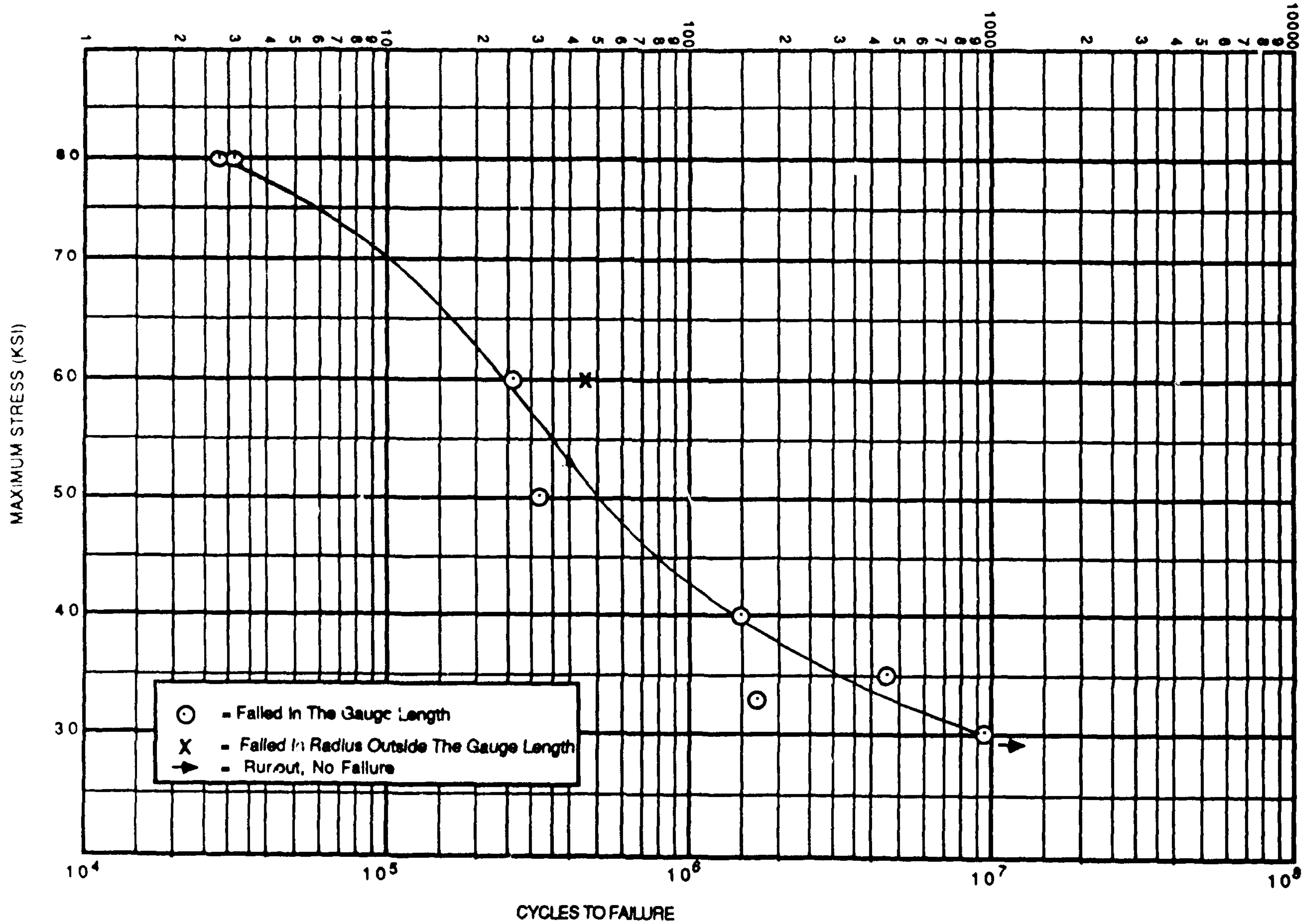



Figure 10. High Cycle Fatigue Results For Specimens With .0025" Recast Layer

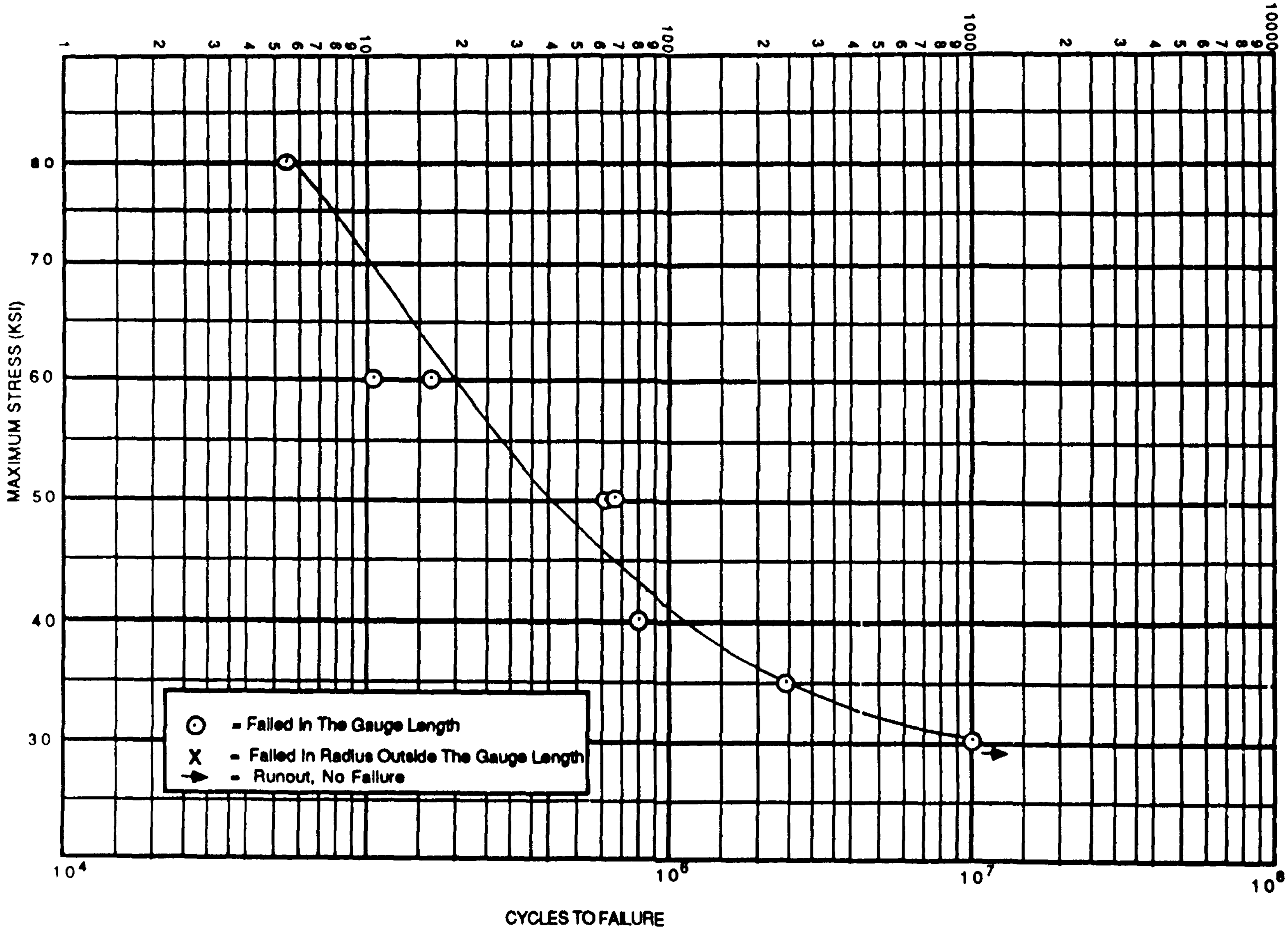



Figure 11. High Cycle Fatigue Results For Specimens With .006" Recast Layer

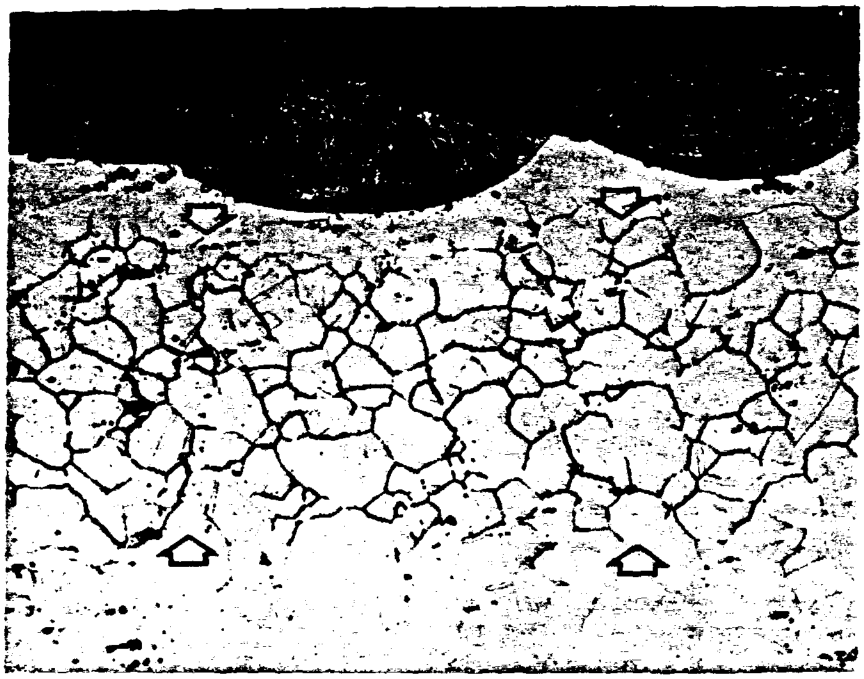


Figure 12. Metallographic cross section of a Hastelloy X laser machined surface showing a .012" thick region of carbide precipitation adjacent to the recast layer (arrows). Mt. No. 90-505, Mag: 125X, Etchant: Electrolytic, 10% Oxalic Acid.

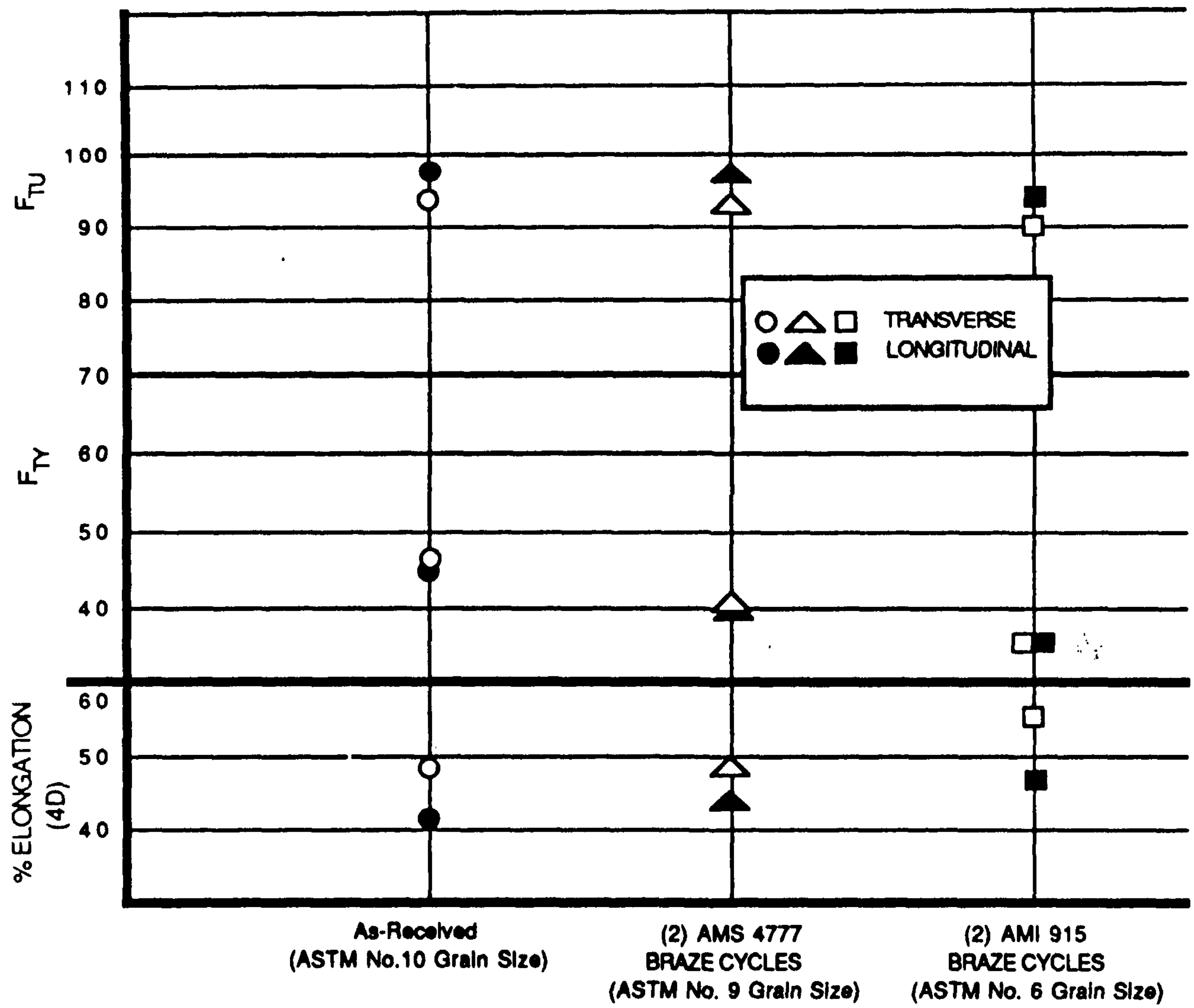



**Figure 13.** Tensile Results For 347 CRES Exposed To Braze Cycles

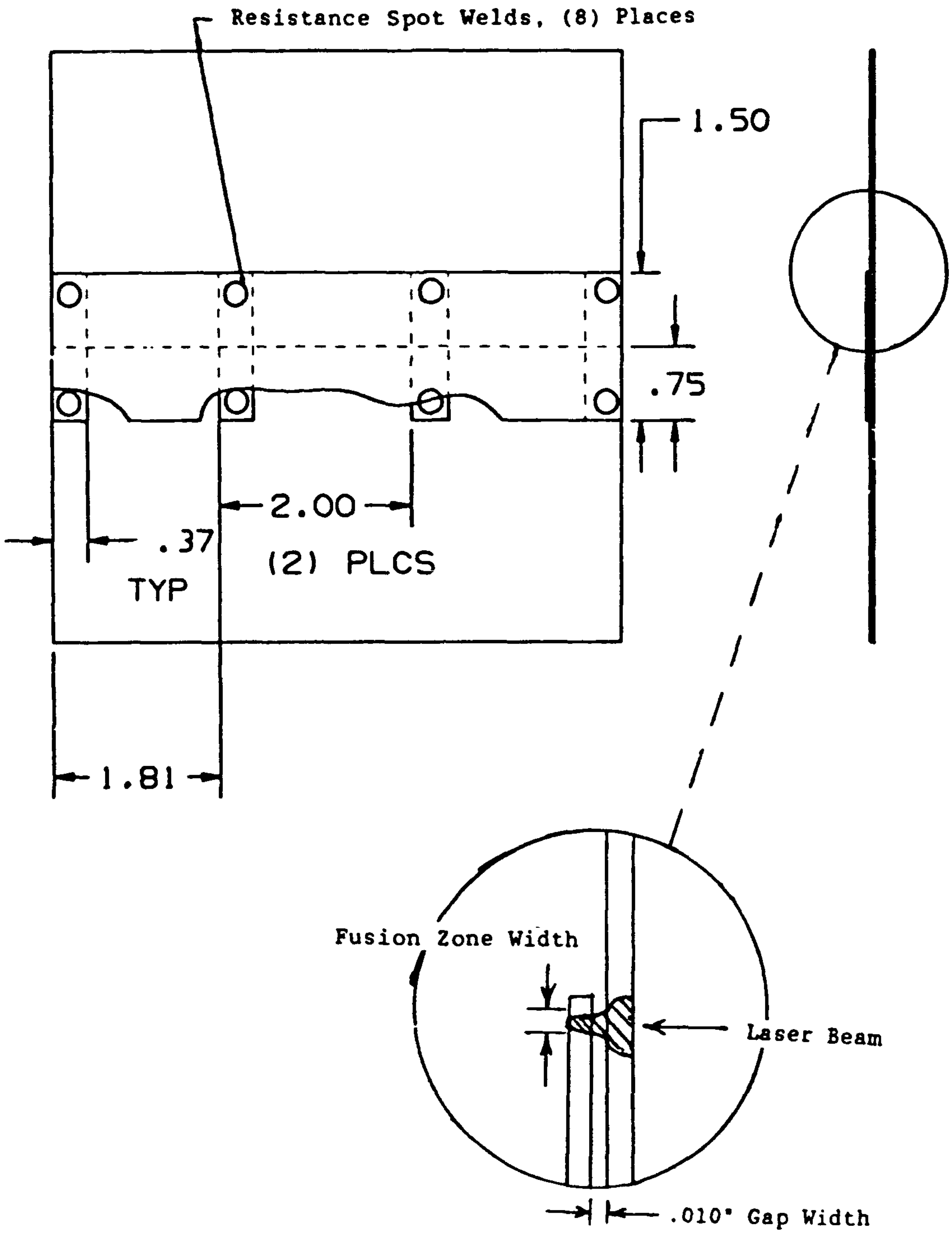



Figure 14. Typical Three Piece Panel Assembly
for Tensile Specimens

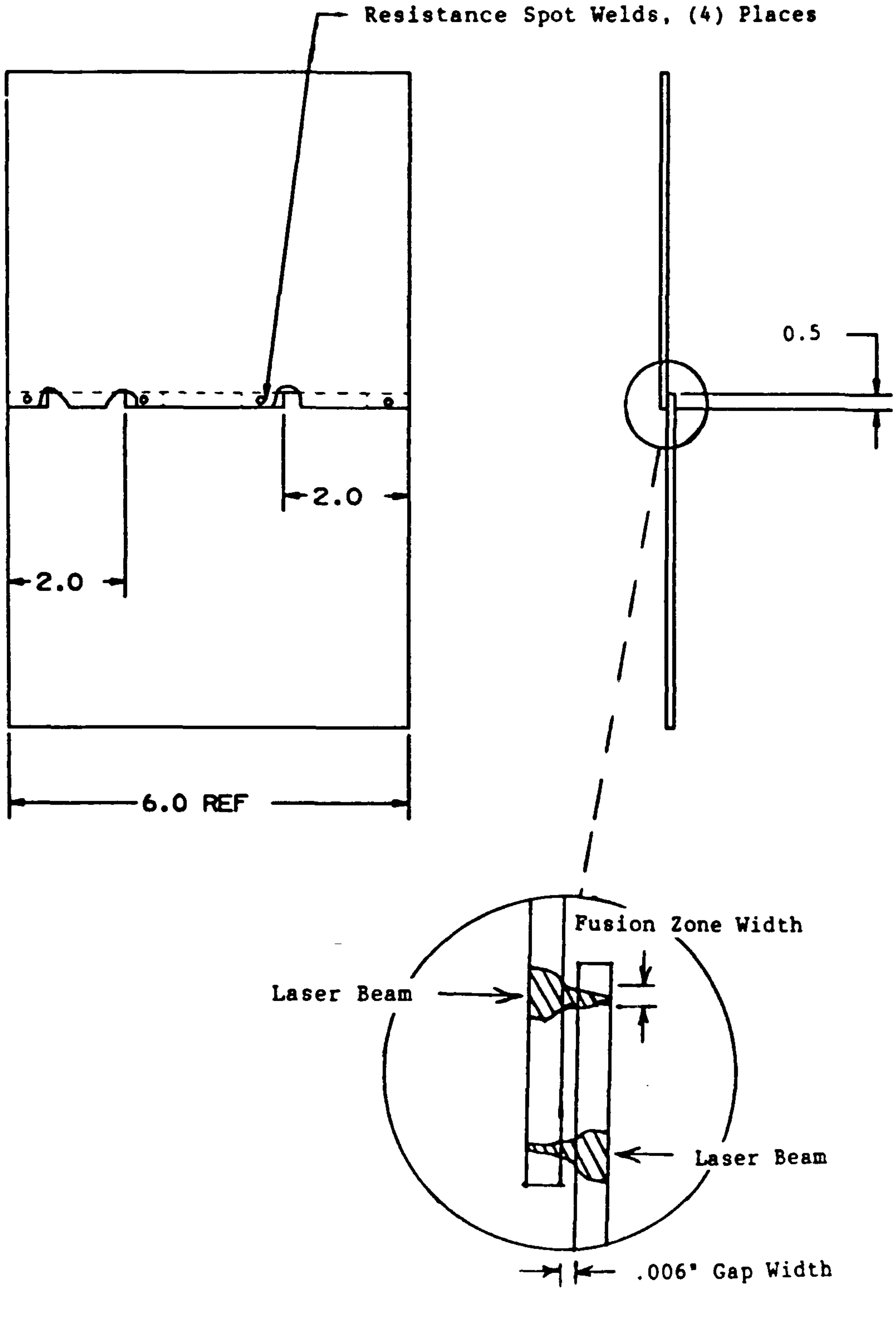



Figure 15. Typical Two Piece Panel Assembly
for Tensile and HCF Specimens

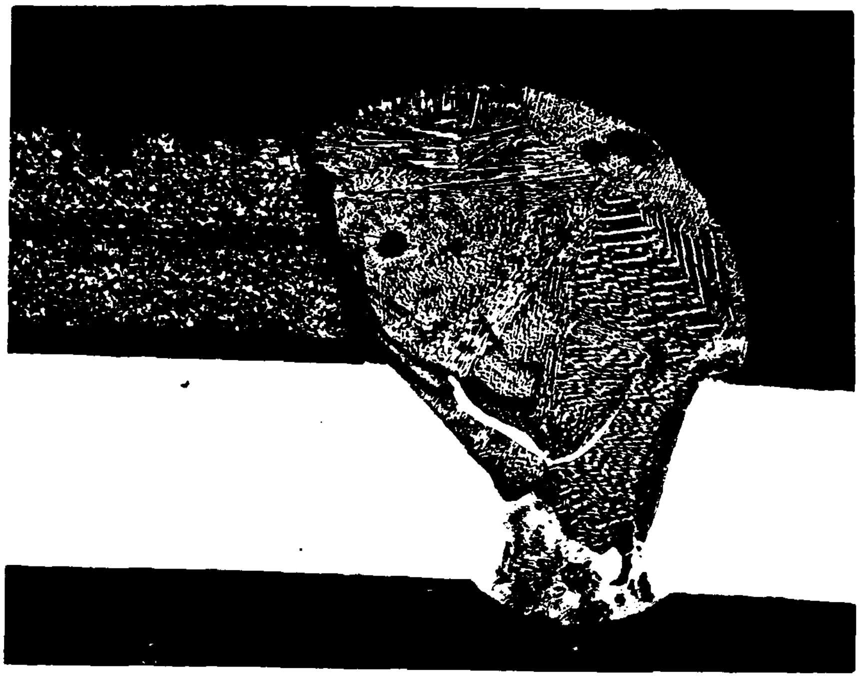


Figure 16. Metallographic cross section of a typical 90° fillet weld of .040" 347 CRES (top) to .040" Hastelloy X. The weld fillets were convex. Mt. No. 90-515, Mag: 26X, Etchant: Glyceregia

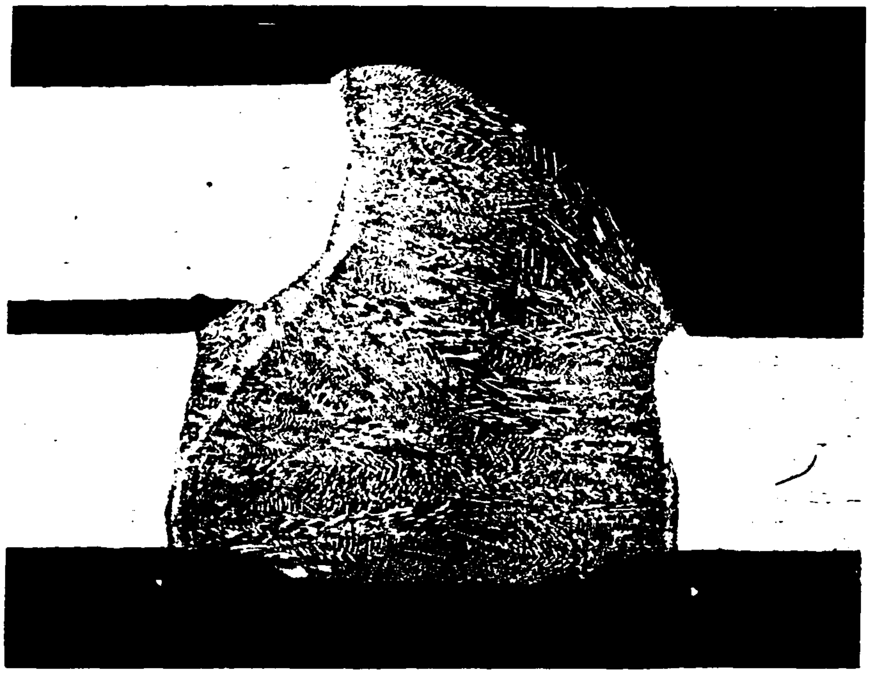


Figure 17. Metallographic cross section of a typical 90° fillet weld of .040" Hastelloy X to .040" Hastelloy X. The weld fillets were slightly convex. Mt. No. 90-515, Mag: 26X, Etchant: Glyceregia

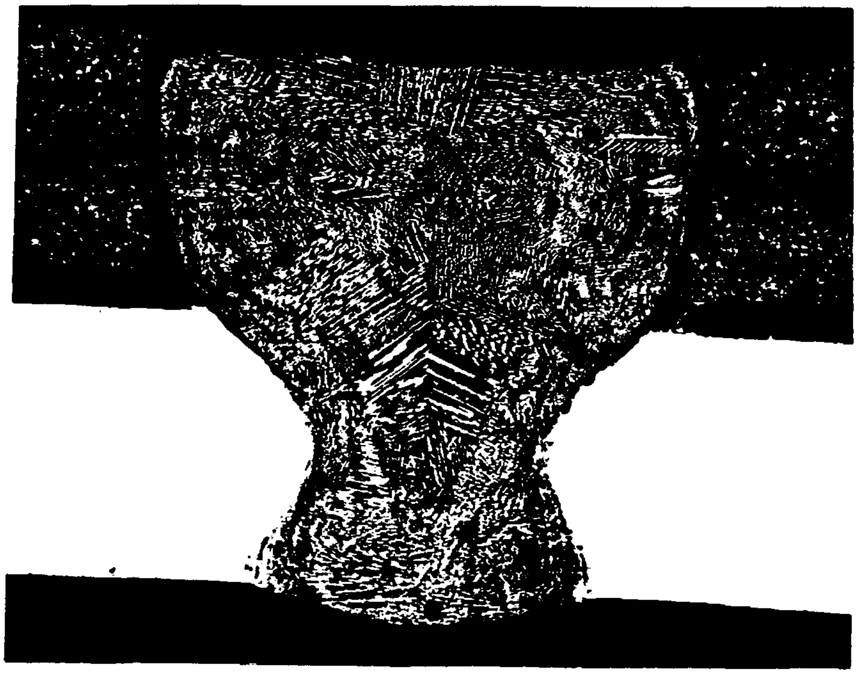


Figure 18. Metallographic cross section of a seam weld of .040" 347 CRES (top) to .040" Hastelloy X. Mt. No. 90-516, Mag: 32X, Etchant: Glyceregia

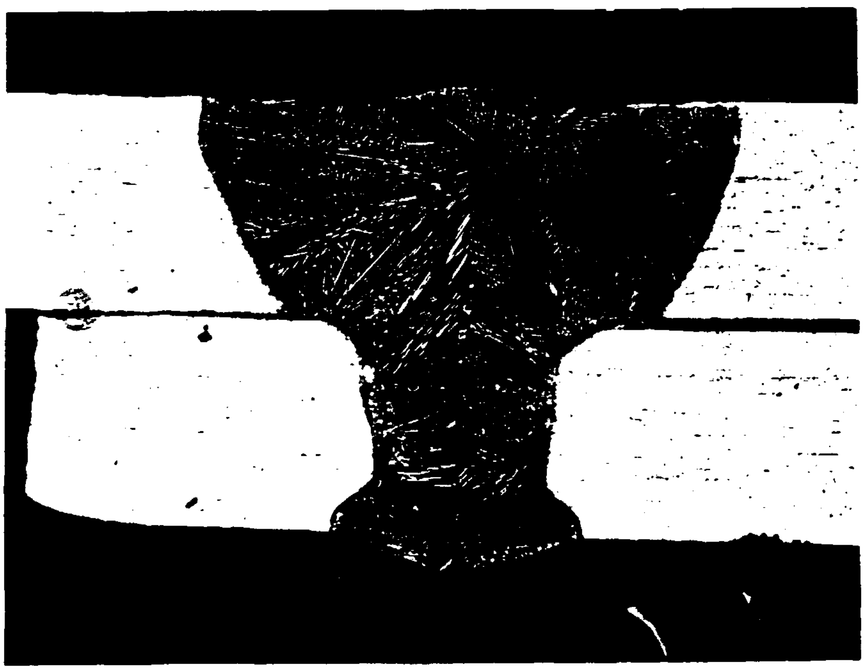


Figure 19. Metallographic cross section of a seam weld of .040" Hastelloy X to .040" Hastelloy X. Mt. No. 90-516, Mag: 32X, Etchant: Glyceregia

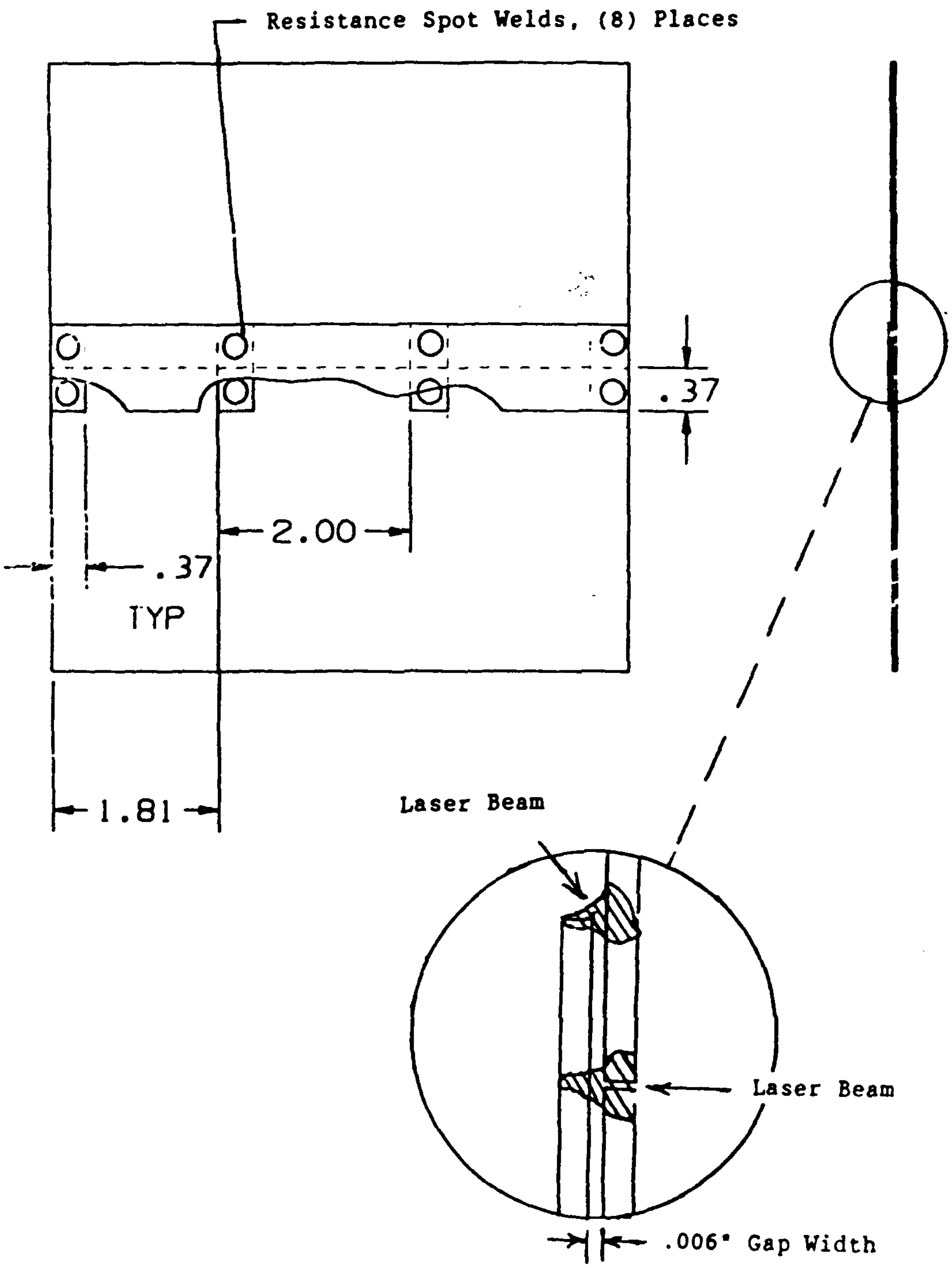



Figure 20. Typical Three Piece Panel Assembly
for HCF Specimens

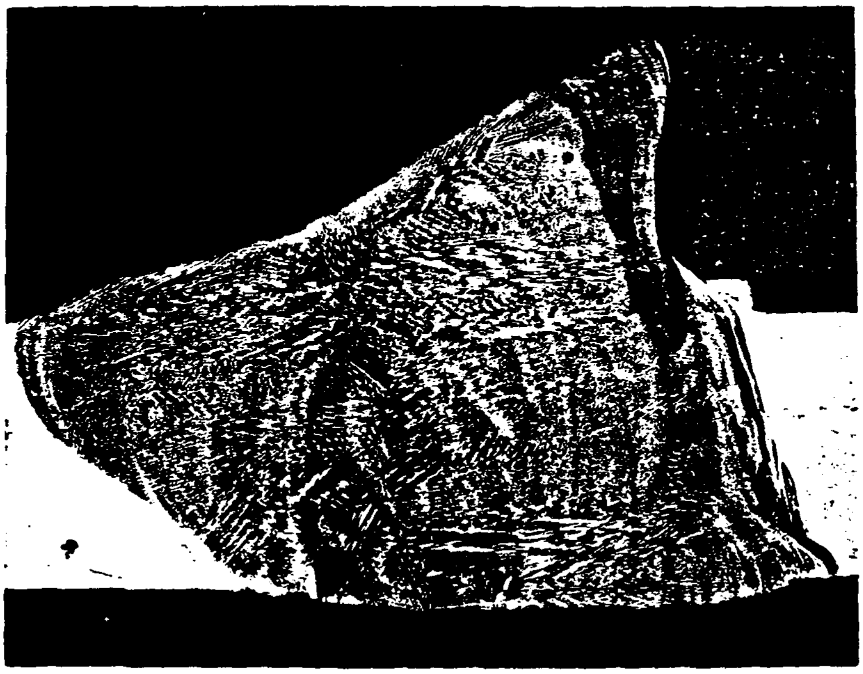


Figure 21. Metallographic cross section of a 45° fillet weld of .040" 347 CRES (top) to .040" Hastelloy X. The weld fillets were concave vs. convex (see Figure 16). Mt. No. 90-516, Mag: 32X, Etchant: Glyceregia

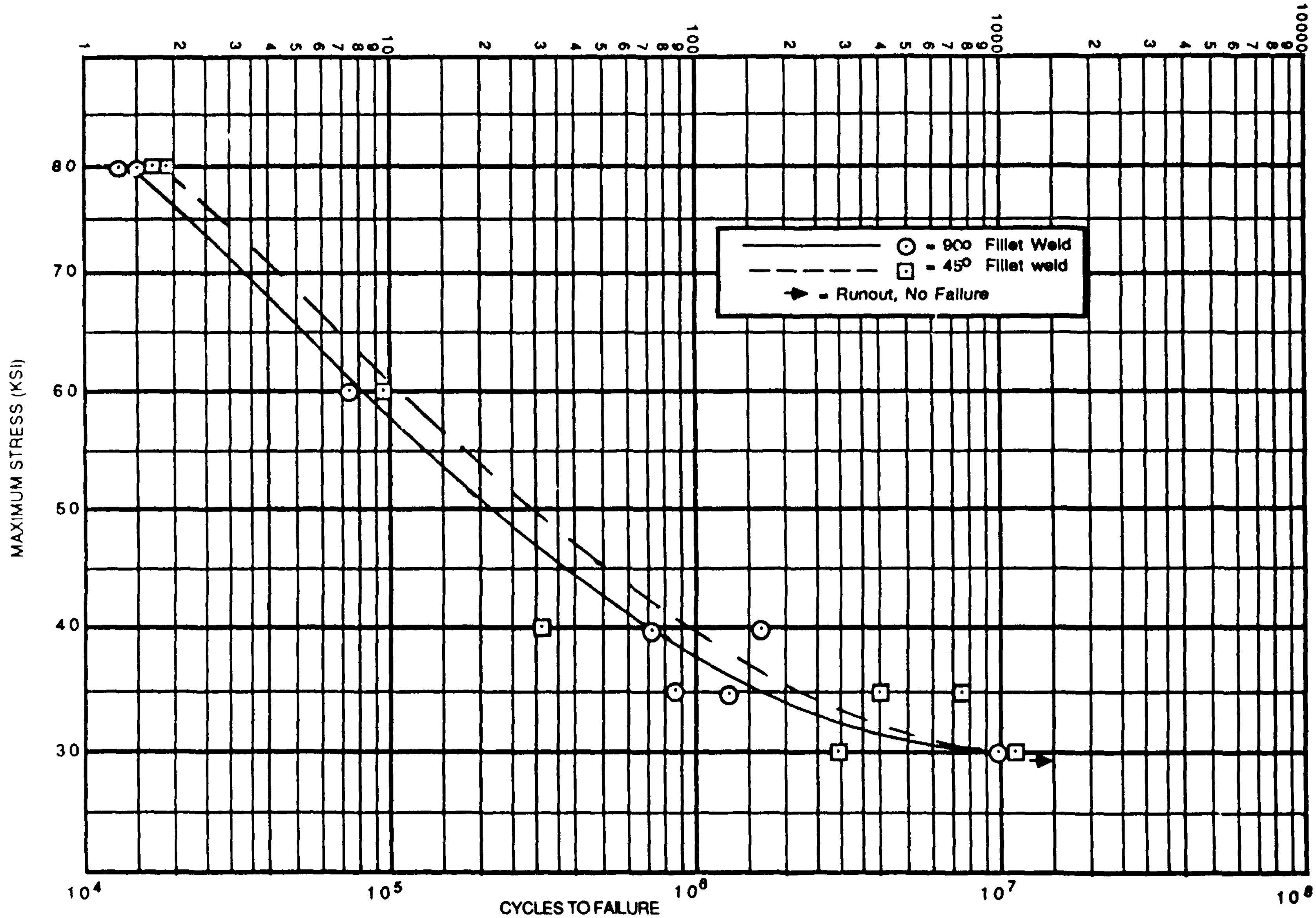



Figure 22. High Cycle Fatigue Results For Laser Welded Three Piece Lap Joint Specimens, .010 Gap Width

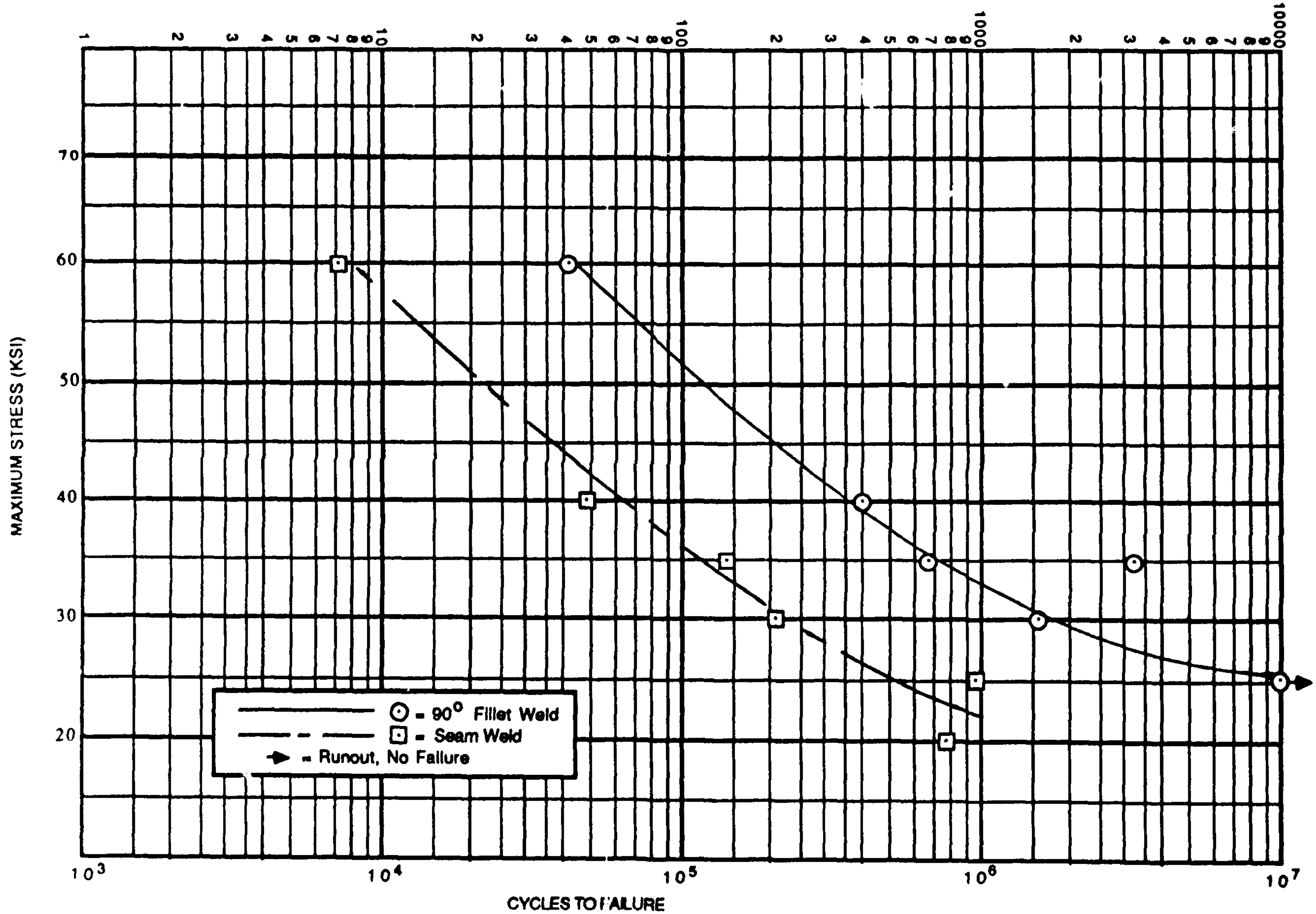



Figure 23. High Cycle Fatigue Results For Laser Welded Two Piece Lap Joint Specimens, .010 Gap Width

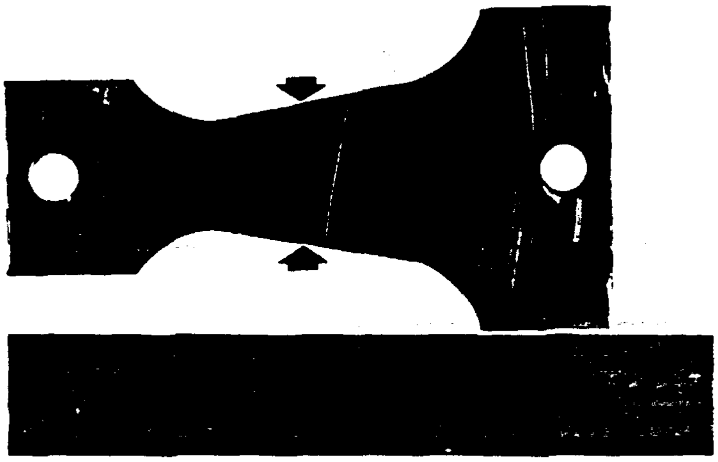


Figure 24. Typical cantilever bending HCF specimen which has been laser machined. The constant stress gauge section is 0.5" long. The dark areas adjacent to the edges of the specimen (arrows) is oxidation cause by the heat generated during laser machining.

Figure 25. Metallographic cross section of a Hastelloy X laser machined surface showing recast layer variability. The recast layer of adjacent areas varies form .0005" to .0044" (arrows). Mt. No. 90-477, Mag: 100X, Etchant: Glyceregia

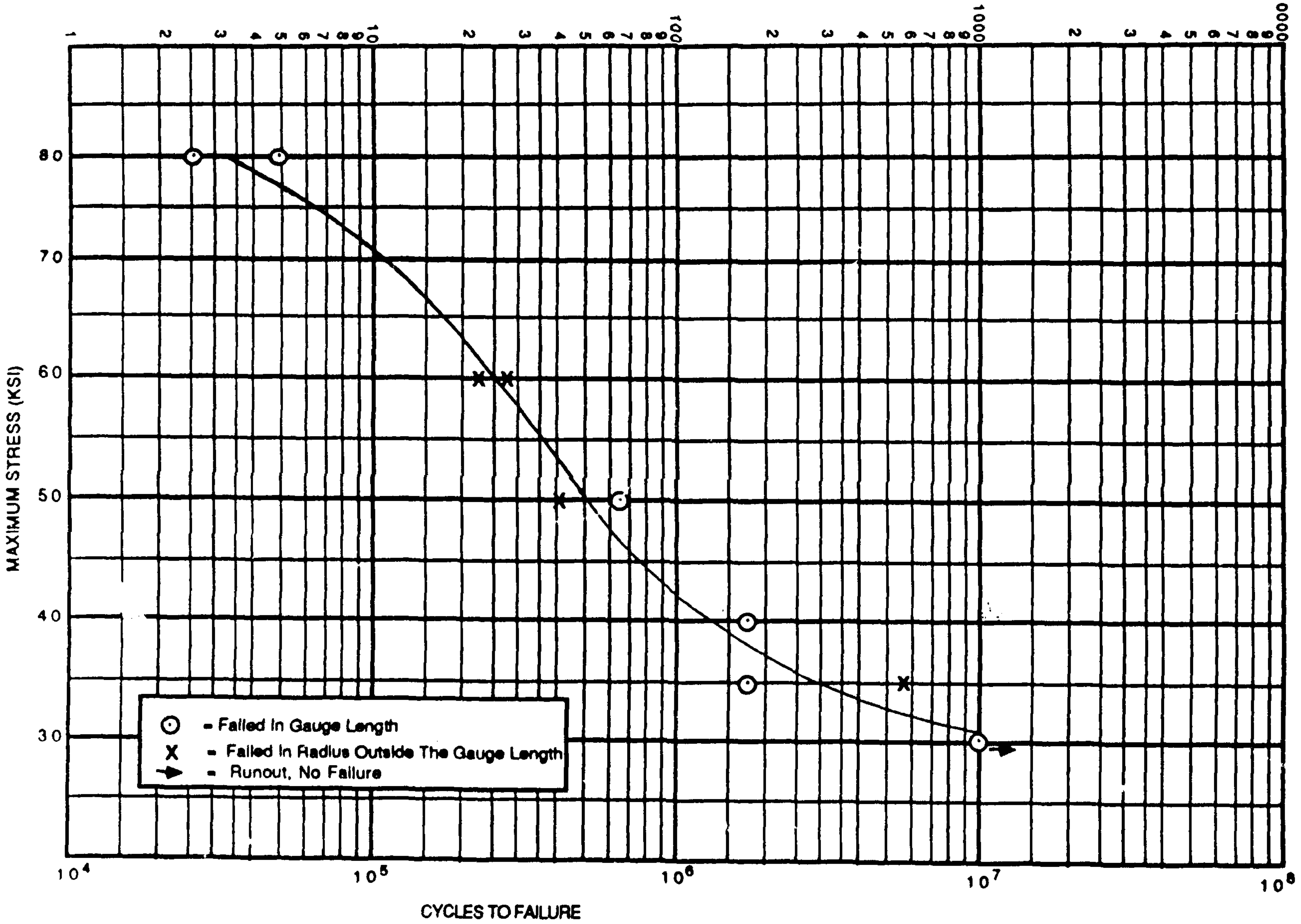



Figure 26. High Cycle Fatigue Results For Specimens With .001" Recast Layer

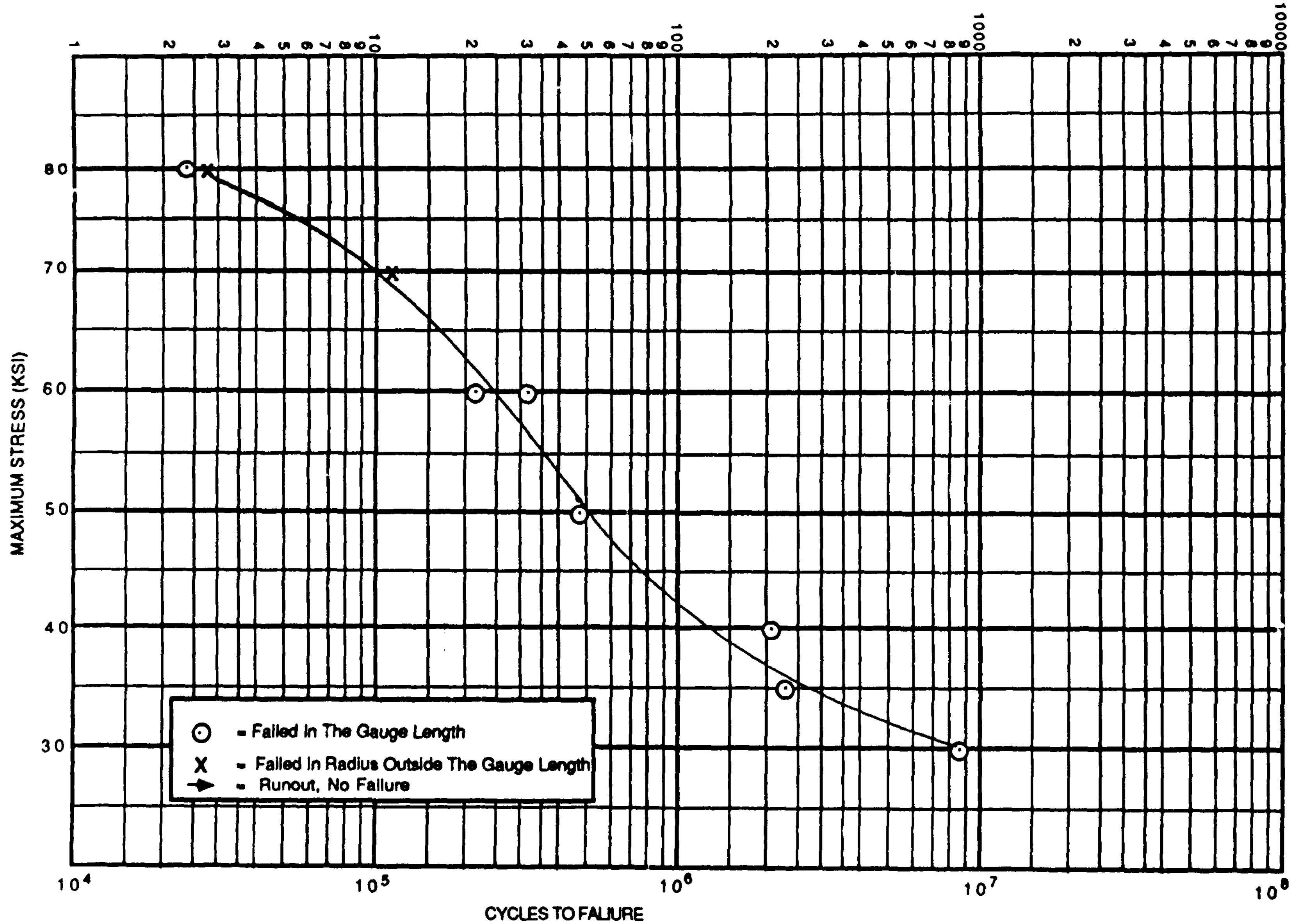



Figure 27. High Cycle Fatigue Results For Specimens With .004" Recast Layer

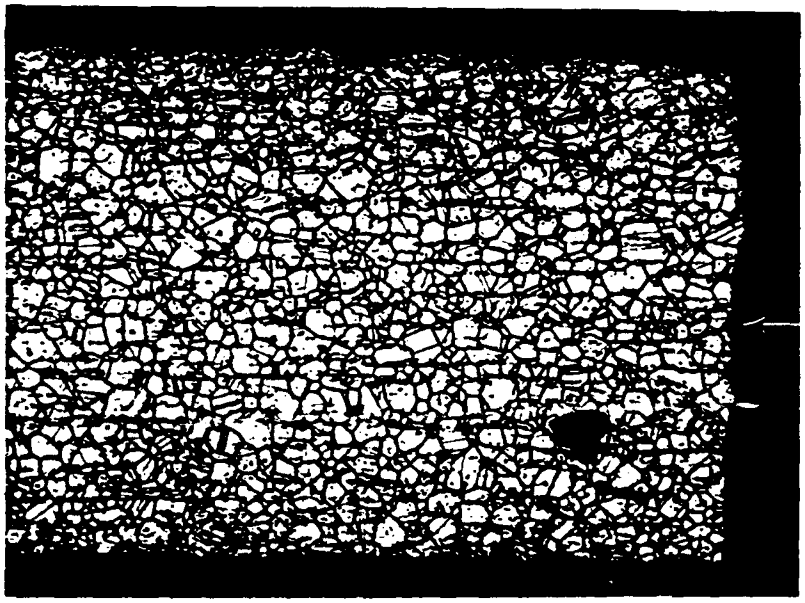


Figure 28. Metallographic cross section of a failed AMS 4777 brazed cantilever bending HCF specimen. The arrow indicates the fracture surface. Grain size is ASTM No. 6.0 through the entire cross section which can be compared to the AMI 915-HT brazed specimen (Figure 29). Mt. No. 91-673, Mag: 64X, Etchant: Electrolytic, 10% Oxalic Acid

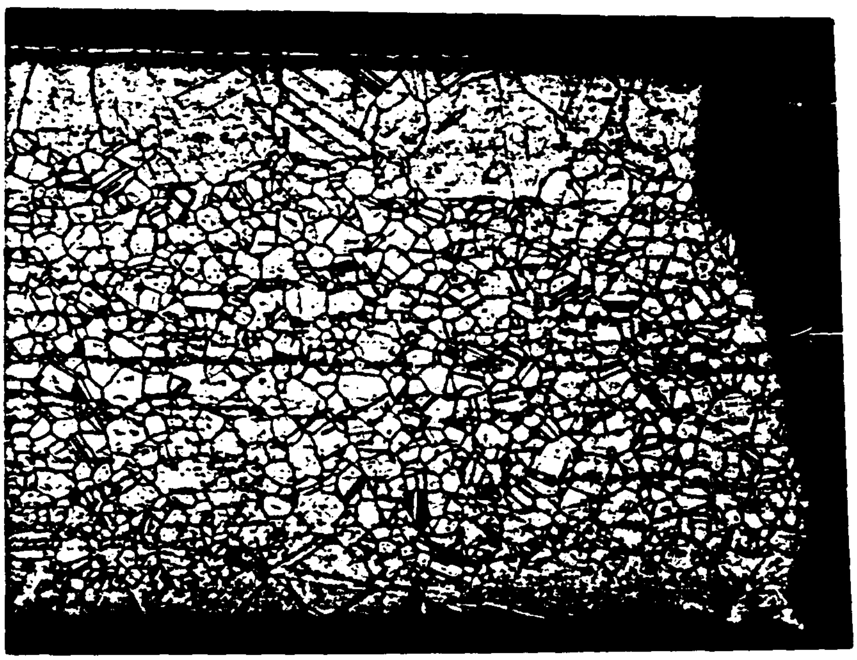


Figure 29. Metallographic cross section of a failed AMI 915-HT brazed cantilever bending HCF specimen. The arrow indicates the fracture surface. Grain size is ASTM No. 5.5 on the interior and 2.5 on the exterior surfaces. This can be compared to the AMS 4777 brazed specimen which had an ASTM 6.0 grain size throughout (Figure 28). Mt. No. 91-672, Mag: 64X, Etchant: Electrolytic, 10% Oxalic Acid

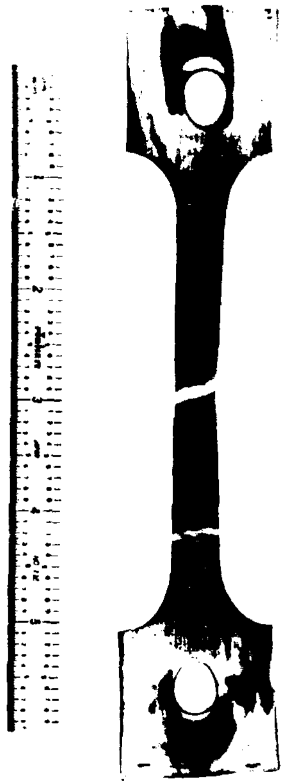


Figure 30. Typical tensile specimen. Tensile specimens were pulled in both the longitudinal and transverse directions.

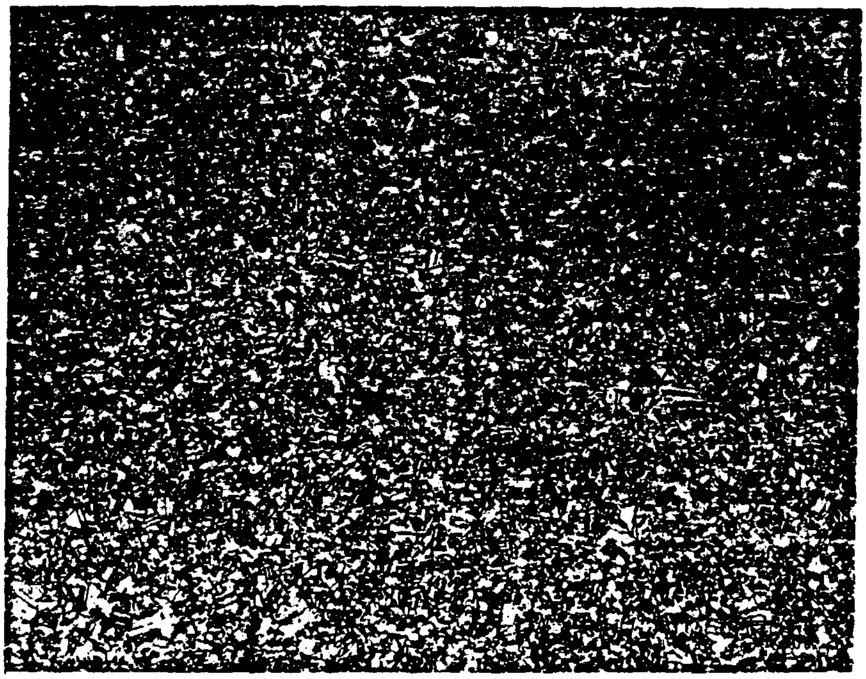


Figure 31. Metallographic cross section of the as-received 347 CRES sheet. Grain size is ASTM No. 10. Mt. No. 90-576, Mag: 100X, Etchant: Electrolytic, 10% Oxalic Acid

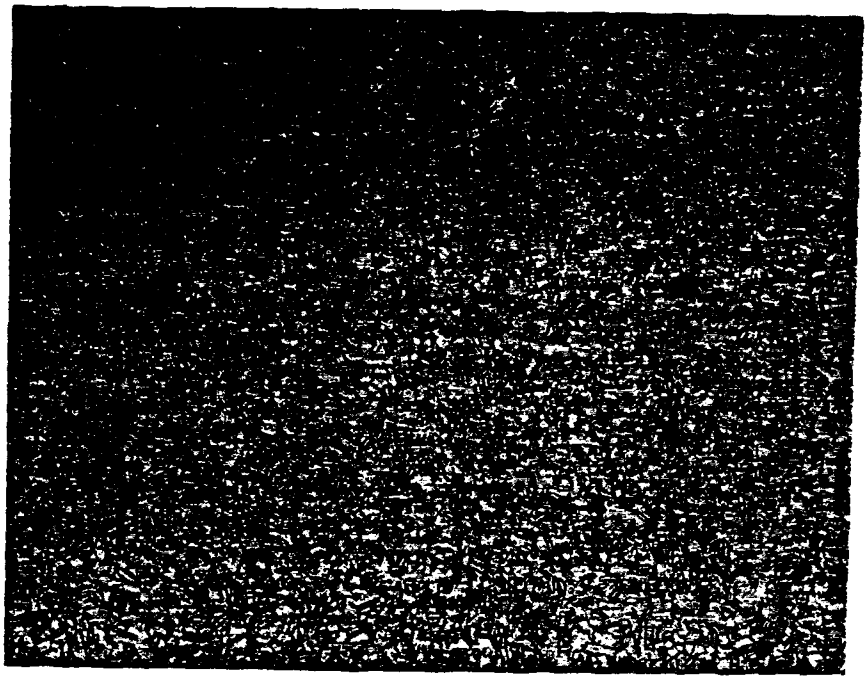


Figure 32. Metallographic cross section of the 347 CRES sheet exposed to (2) AMS 4777 braze cycles. Grain size is ASTM No. 9.0. Mt. No. 90-580, Mag: 100X, Etchant: Electrolytic, 10% Oxalic Acid

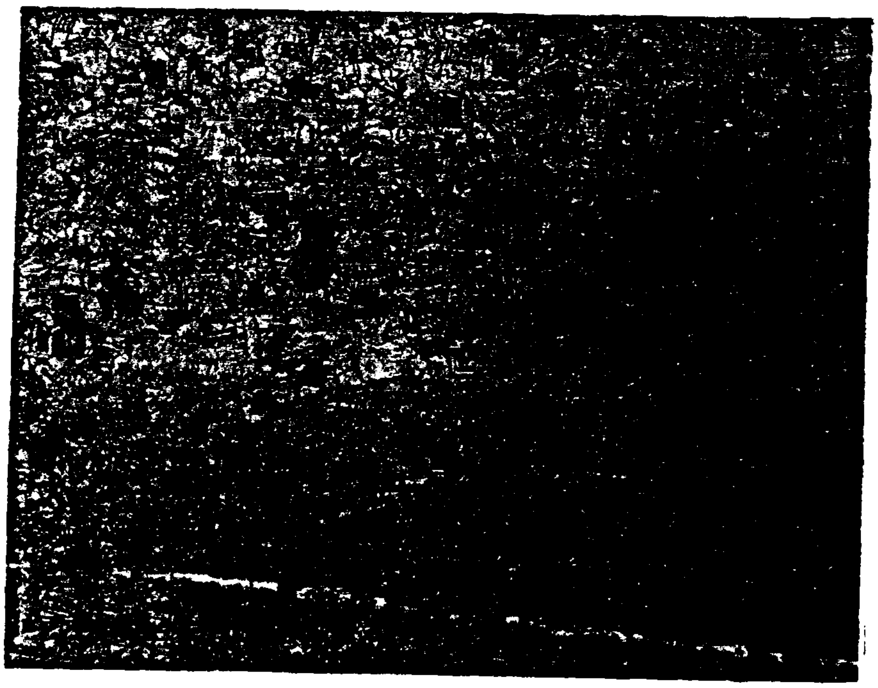


Figure 33. Metallographic cross section of the 347 CRES sheet exposed to (2) AMI 915 braze cycles. Grain size is ASTM No. 6.0. Mt. N Etchant: Electrolytic, 10% Oxalic Acid

## TABLE I. TENSILE RESULTS FOR LASER WELDED SPECIMENS

| Weld Joint Design/Weld Type | Fusion Zone Width (inch) | Gap Width (inch) | Average[1] Yield Str. (0.2%, ksi) | Average[1] Tensile Str. (ksi) |
|---|---|---|---|---|
| Three Piece Lap Joint/Fillet | .040 | .006 | 35.1 | 94.2 |
| | .040 | .010 | 37.2 | 92.4 |
| Three Piece Lap Joint/Seam Weld | .040 | .006 | 35.8 | 87.4 |
| | .040 | .010 | 33.1 | 87.4 |
| | .080 | .006 | 40.6 | 94.9 |
| | .080 | .010 | 37.2 | 92.4 |
| Two Piece Lap Joint/Fillet | .040 | .006 | 59.0 | 115.9 |
| | .040 | .010 | 59.0 | 118.6 |
| Two Piece Lap Joint/Seam Weld | .040 | .006 | 56.1 | 115.6 |
| | .040 | .010 | 56.7 | 115.0 |
| | .080 | .006 | 55.3 | 114.0 |
| | .080 | .010 | 57.6 | 118.4 |

1. Average value from four tensile specimens.

TABLE II. HIGH CYCLE FATIGUE RESULTS FOR LASER WELDED SPECIMENS, .006" GAP WIDTH

| Weld Joint Design/Weld Type | Maximum Stress (ksi) | Fatigue Life (cycles) |
|---|---|---|
| Two Piece Lap Joint/90° Fillet | 80 | 8,200 |
| | 70 | 18,300 |
| | 70 | 24,100 |
| | 60 | 47,200 |
| | 40 | 291,300 |
| | 30 | 1,352,300 |
| | 30 | 2,140,600 |
| | 25 | >10,000,000 |
| Two Piece Lap Joint/Seam Weld | 80 | 4,100 |
| | 60 | 43,900 |
| | 60 | 84,000 |
| | 40 | 153,200 |
| | 40 | 393,300 |
| | 30 | 2,178,400 |
| | 30 | 4,930,900 |
| | 25 | >10,000,000 |
| Three Piece Lap Joint/45° Fillet | 80 | 20,200 |
| | 80 | 26,300 |
| | 60 | 61,800 |
| | 60 | 239,100 |
| | 40 | 949,500 |
| | 40 | 1,971,900 (1) |
| | 35 | 2,769,400 |
| | 30 | 1,214,700 |
| Three Piece Lap Joint/90° Fillet | 80 | 7,400 |
| | 70 | 23,900 |
| | 60 | 50,800 |
| | 40 | 253,000 |
| | 30 | 1,075,500 |
| | 30 | 3,295,600 |
| | 25 | 3,543,500 |
| | 25 | 3,742,900 |

(1) Failed in parent metal away from weld joint.

TABLE III. HIGH CYCLE FATIGUE RESULTS FOR LASER WELDED SPECIMENS, .010" GAP WIDTH

| Weld Joint Design/Weld Type | Maximum Stress (ksi) | Fatigue Life (cycles) |
|---|---|---|
| Two Piece Lap Joint/90° Fillet | 60 | 42,300 |
| | 40 | 395,200 |
| | 35 | 676,800 |
| | 35 | 3,337,100 (1) |
| | 30 | 1,568,700 |
| | 25 | >10,000,000 |
| Two Piece Lap Joint/Seam Weld | 60 | 7,300 |
| | 40 | 48,700 |
| | 35 | 136,900 |
| | 30 | 210,200 |
| | 25 | 939,600 |
| | 20 | 770,900 |
| Three Piece Lap Joint/45° Fillet | 80 | 17,100 |
| | 80 | 17,900 |
| | 60 | 96,200 |
| | 40 | 319,200 |
| | 35 | 4,191,000 |
| | 35 | 7,652,400 |
| | 30 | 2,962,400 |
| | 30 | >10,000,000 |
| Three Piece Lap Joint/90° Fillet | 80 | 13,800 |
| | 80 | 15,000 |
| | 60 | 74,900 |
| | 40 | 711,000 |
| | 40 | 1,732,200 |
| | 35 | 833,300 |
| | 35 | 1,311,800 |
| | 30 | >10,000,000 |

(1) Failed in parent metal away from weld joint.

TABLE IV. HIGH CYCLE FATIGUE RESULTS FOR RECAST LAYER SPECIMENS

| Recast Layer Depth (inches) | Maximum Stress (ksi) | Fatigue Life (cycles) |
|---|---|---|
| Machined | 80 | 20,800 |
| | 80 | 22,200 |
| | 70 | 132,400 |
| | 70 | 147,400 |
| | 60 | 352,900 |
| | 50 | 1,540,100 |
| | 50 | 2,013,800 |
| | 40 | 6,232,500 |
| | 40 | 8,506,800 |
| .001 | 80 | 24,700 |
| | 80 | 47,900 |
| | 60 | 222,200 (1) |
| | 60 | 268,700 (1) |
| | 50 | 395,400 (1) |
| | 50 | 699,000 |
| | 40 | 1,675,500 |
| | 35 | 1,706,000 |
| | 35 | 5,415,600 (1) |
| | 30 | >10,000,000 |
| .0025 | 80 | 28,800 |
| | 80 | 32,800 |
| | 60 | 270,900 |
| | 60 | 496,700 (1) |
| | 50 | 378,600 |
| | 40 | 1,481,100 |
| | 35 | 4,301,400 |
| | 33 | 1,714,400 |
| | 30 | >10,000,000 |
| .004 | 80 | 24,300 |
| | 80 | 28,600 (1) |
| | 70 | 108,600 (1) |
| | 60 | 217,900 |
| | 60 | 307,700 |
| | 50 | 477,400 |
| | 40 | 2,073,200 |
| | 35 | 2,219,900 |
| | 30 | 8,975,700 |
| .006 | 80 | 51,600 |
| | 60 | 99,400 |
| | 60 | 165,900 |
| | 50 | 600,200 |
| | 50 | 673,500 |
| | 40 | 772,100 |
| | 35 | 2,367,100 |
| | 30 | >10,000,000 |

(1) Failed in the radius outside the gauge length.

TABLE V. HIGH CYCLE FATIGUE RESULTS FOR BRAZED SPECIMENS

| Braze Joint Design/Braze Alloy | Maximum Stress (ksi) | Fatigue Life (cycles) |
|---|---|---|
| Three Piece Lap Joint/AMS 4777 | 60 | 171,000 |
| | 50 | 804,000 |
| | 47 | 1,581,000 |
| | 45 | 973,000 |
| | 43 | 1,017,000 |
| | 40 | 8,171,000 |
| | 37 | 4,247,000 |
| | 37 | 6,565,000 |
| | 35 | >10,000,000 |
| Three Piece Lap Joint/AMI 915 | 60 | 123,000 |
| | 50 | 344,000 |
| | 45 | 816,000 |
| | 43 | 907,000 |
| | 40 | 1,302,000 |
| | 37 | 6,225,000 |
| | 35 | 4,993,000 |
| | 33 | 7,597,000 |
| | 32 | >10,000,000 |
| | 30 | >10,000,000 |
| Three Piece Lap Joint/AMI 915-HT | 60 | 84,000 |
| | 50 | 309,000 |
| | 45 | 742,000 |
| | 43 | 1,120,000 |
| | 40 | 1,404,000 |
| | 37 | 2,295,000 |
| | 35 | 4,586,000 |
| | 33 | >10,000,000 |

**TABLE VI. TENSILE RESULTS FOR THE 347 CRES SHEET EXPOSED TO BRAZE CYCLES**

| Heat Treatment | Orientation | Tensile Strength (ksi)[1] | Yield Strength (ksi)[1] | Elongation (4D)[1] |
|---|---|---|---|---|
| As-Recieved | L | 96.8 | 45.0 | 41.5 |
| | T | 94.0 | 46.1 | 47.8 |
| Two AMS 4777 Braze Cycles | L | 97.0 | 39.7 | 43.8 |
| | T | 92.3 | 40.4 | 48.8 |
| Two AMI 915 Braze Cycles | L | 92.8 | 35.8 | 46.3 |
| | T | 89.8 | 36.3 | 53.8 |

1. Average value from four specimens.

# 6.0 IMPLEMENTATION PLAN

## 6.1 PRIMARY OBJECTIVE

The new one-piece combustor housing design is complete. At present all detail parts are purchased items manufactured by vendors to Sundstrand engineering drawings. These parts are assembled in-house at Sundstrand.

The primary objective of the IMIP Phase II project was to establish the necessary equipment, facility requirements, engineering specifications, and implementation plan for the Sundstrand Precision Metal Forming Cell. This new facility will have the capability to fabricate all sheet metal parts in support of the flow formed combustor housing assemblies. A detailed "Make or Buy" list is shown in Figure 6-1.

## 6.2 CAPITAL EQUIPMENT REQUIREMENTS AND SELECTION

A list of equipment for the Precision Metal Forming Cell is shown in Figure 6-2. This is the equipment required to support the planned flow forming and laser welding method of manufacturing.

### 6.2.1 FLOW FORMING LATHE

The procurement specification for this equipment requires a minimum of two roller heads with a capability of forming a .375 inch thick Hastelloy "X" blank, down to a thickness of .020 inches. The lathe shall be capable of forming angles and Radii of .030 inches.

This lathe is considered a medium heavy machine which requires special cylindrical components with high accuracy. Machine range shall be from 2 inches through 24 inches in diameter and a length capacity of 49 inches (forward) and 98 inches (reverse). The machine shall have spindle rotation of 35 to 875 rpm and a feed rate of 0.4 to 38 inches per minute.

Requests for quotations were sent to all flow form lathe producers. A team was formed to review and compare actual performance against quoted capabilities to support final selection.

The only quotations received were from Bohner and Kiale GmbH & Co. (BOKO) and Autospin, Inc. (Leifeld). The price of this equipment includes a complete set of formal drawings, wiring diagrams, schematics, training for SPS personnel, and all operating, repair, etc. manuals.

The BOKO unit was selected, reference Figure 6-3. The main reasons are they have more experience, and appear to be better capable of meeting all contract requirements. However, each supplier was asked to produce a part similar to the housing in design shape and thickness using 100% flow forming. Final selection was based primarily on their ability to fabricate the part. Both suppliers, Leifeld and BOKO, are sure that they can produce the part. This is a step in the right direction as neither supplier thought they could do this a few months ago. Leifeld refused to compete with BOKO. The only way they would fabricate a part was for Sundstrand to contract with them to build the necessary tooling and would guarantee that Sundstrand would select them if they were successful in fabricating the part using 100% flow forming.

BOKO did fabricate a part similar to the housing configuration from a flat sheet of Hastelloy X thru completion using 100% flow forming without any annealing operations. As stated above, training is part of the contract with BOKO and Sundstrand expects this to be a successful operation with minimum time once the equipment is installed.

### 6.2.2 CO2 LASER UNIT

The procurement specification for this unit requires the unit to be a computer controlled 1500 watt CO2 fast axial pulsed laser which can be used for welding, drilling, and cutting.

The CO2 laser shall have the capability to weld, drill, and cut high temperature nickel alloys. A weld depth penetration of .150 inches is required. It shall be capable of making holes from .01Γ inches to 10.0 inches in diameter with hole entrance angles of 10 degrees. It shall be able to cut material from .250 to .500 inches thick. The laser shall be capable of c. puter programmable power settings. The price of the laser unit like the flow forming lathe will include drawings, wiring diagrams, schematics, training for SPS personnel, etc.

A request for quote was sent to eight laser manufacturers and laser machine builders. They are:

| | | |
|---|---|---|
| S.E. Huffman Corp.<br>Clover, SC 29710 | Rofin Sinar Laser<br>Vista, CA 92084 | Trumpf Industrial Lasers<br>Laguna Hills, CA 92653 |
| Lumonics Laser Systems<br>Pleasanton, CA 94588 | Coherent General<br>San Diego, CA 92128 | Raycon Corporation<br>Ann Arbor, MI 48105 |
| Amada Laser Systems<br>Buena Park, CA 90621 | Utilase<br>Detroit, MI 48205 | |

Only Amada Laser Systems did not respond. SPS employed Mr. Belforte, an expert in industrial technology, to review and aid SPS in equipment and supplier selection. Referenced vendor quotations are in Appendix A.

Review covered material penetration per kilowatt of power, beam mode quality, fixturing, end piece production, and quality. Of the bids received and reviewed, Trumpf Industrial, Lumonics Lasers, and Raycon Corporation are the most promising. A visit to each was accomplished and the final selection went with Lumonics, reference Figure 6-4. The primary feature with this unit is that it has an enclosed section where the laser process is in operation. The work table slides from side to side allowing set or removal operations to occur in parallel with the laser operation.

### 6.2.3 HYDRAULIC SHEER

Shears must have a minimum capacity to accept 6 foot wide material with a thickness up to 3/16 inches. It must be able to shear 321 SS (100,000 psi), 347 SS (105,000 psi), and Hastelloy X (113, 000 psi). It was also requested that each supplier state their maximum and minimum capability for each material to determine equipment safety factors. Machines shall be wired for 440 volt, 3 phase, 60 cycle, with only one current supply for all functions.

The RFQ included Operator Manuals, Programmer Manuals, Electrical Wiring and Schematic Diagrams, plus Service, Maintenance, and Repair Manuals. Each supplier was asked to supply SPS personnel training.

Request for specifics on design for features such as squaring material with the blade, number of hold downs, positioning accuracy, repeatability, etc., be provided.

RFQ's were sent to 6 sources of equipment. They were:

| | | |
|---|---|---|
| Cincinnati<br>Alahambra, CA 91801 | Niagara<br>Brea, CA 92621 | Darley Essa International<br>Santa Fe Springs, CA 90670 |
| U.S. Amada, ltd<br>Buena Park, CA 90621 | Wysong and Miles Co.<br>Escondido, CA 92025 | Pacific Press & Shear Co.<br>Anaheim, CA 92805-5651 |

Summary of Quotations are as follows:

| ITEM | CINCINNATI | AMADA | DARLRY | NIAGARA | PACIFIC/HTC | WYSONG |
|---|---|---|---|---|---|---|
| Type | Hydraulic | Mechanical | Swing Arm | Hydraulic | Hydraulic | Mechanical |
| Thickness X Long | 1/4 X 6' | 1/4 X 6' | .156 x 6' | 1/4 x 10' | 1/4 X 10' | .156 X 6' |
| Base Cost $ | 42,540 | 45,000 | 30,543 | 33,347 | 29,900 | 37,000 |
| Light Beam | 920 | STD | STD | STD | STD | 1,150 |
| Extra Knives | 2,390 | 1,010 | 2,600 | 2,600 | 910 | 1,600 |
| Total Price | 49,063<br>39,700 | 50,000 Est. | | 36,000 Est. | 39,000 Est. | 35,300 |
| Hold Downs | 8 | 9 | 10 | 12 | 13 | 11 |

Of the 6 vendors listed above, the Niagara Spartan SP1/4-10 was selected. This shear qualified to the Machine Tool Matrix and was within the cost budget planned for this unit. This shear has all of the features required for a precision sheet metal facility. It has an adjustable power operated rake angle, thus the operator will be able to adjust the angle at the cutting blade to minimize distortions of the finished work and allow the shear to cut to its maximum capacity.

The variable blade clearance adjustment is accomplished by means of two levers at the rear of the shear and will allow the shear to cut different thicknesses with a minimum of burrs. Both of these features will provide this shear the versatility required to accommodate the different thicknesses and materials used in SPS sheet metal products.

The underdrive feature of this shear enhances its ability to resist shearing forces without the need for heavy side frames and special foundations. This shear can be mounted on any solid floor and has built-in leveling screws.

The front-operated power package (push button controlled with digital indicator display) will provide the accuracy and repeatability required. This package has a built-in shock absorber to cushion impact loads as the operator slides the sheet into position.

Niagara Machine and Tool Works are a leading manufacturer of hydraulic shears and have designed and built this shear using years of experience and knowledge.

### 6.2.4 100 TON HYDRAULIC PRESS

This shall be an Open Gap Hydraulic Guided Press, with a capacity of 100 Tons, stroke minimum of 8 inches, open height 20 inches minimum, and shut height of 8 inches. The press shall have light curtain with interlocking guards. Ram platen size, front to back and side to side shall be 12 inches minimum.

Electrical cabinets are to meet or exceed N.E.M.A. standards. All electrical and electronics must conform to all Federal, California State, and San Diego local codes, laws, and regulations. All electronics to be protected by dust free enclosures.

All price quotes shall include Operator's, Programmer's, Service, Maintenance, and Repair manuals plus training.

RFQ's were sent to 6 sources of equipment. They were:

| | | |
|---|---|---|
| Cincinnati<br>Alahambra, CA 91801 | Niagara<br>Brea, CA 92621 | Komatsu Ltd.<br>Santa Fe Springs, CA 90670 |
| U.S. Amada, ltd<br>Buena Park, CA 90621 | Greenerd Press<br>Escondido, CA 92025 | Pacific Press & Shear Co.<br>Anaheim, CA 92805-5651 |

Summary of quotations is as follows:

| ITEM | CINCINNATI | KOMATSU | PACIFIC | GREENERD |
|---|---|---|---|---|
| BASE PRICE | 71,191 | 59,879 | 43,500 | 197,000 |
| INSTALLATION | 3,500 | 4,540 | 4,000 | STD. |
| LIGHT CURTAIN | 3,800 | 8,000 | 4,500 | STD. |
| AUTO LUBE | STD. | 1,800 | STD. | STD. |
| DIE CUSHION | STD. | 10,000 | 5,000 | STD. |
| TOTAL | 80,400 | 84,719 | 57,000 | 197,000 |
| | | | | |
| STROKE | 8 | 18 | 12 | 18 |
| OPENING | 15 | 24 | 20 | 32 |
| THROAT | 14 | 12 | 30 | ? |
| MOTOR hp | 20 | 20 | 30 | ? |
| WEIGHT lbs | 16,000 | 12,000 | 20,000 | 36,000 |

The Pacific HTC Model CFP100G, 100 ton guided C-frame hydraulic press was selected for its rugged construction along with the ability to handle a variety of work. This press will be ordered with a 23 inch open height that will allow for the tallest parts and a 18 inch stroke to run dies as small as 5 inches. With an automatic lubrication system, this press will permit a minimum of maintenance. The 100 ton force is available throughout the stroke and the ram has 3 traveling speeds. Approach speed of 318 inches per minute, forming speed of 162 inches per minute, and a return speed of 330 inches per minute.

### 6.2.5 400 TON HYDRAULIC PRESS

The 400 ton press will be used for the flow preform blank and for final sizing after forming. The requirements for this are the same as the 100 ton press except for a larger capacity and working load. This press will be purchased with a 3.5 to 4.0 foot stroke.

Pacific HTC offers a 400 ton press and Sundstrand can save money by a purchase of both the 100 ton and 400 ton presses. A final selection has not been made at this time because detail requirements for this press have not been completed.

### 6.2.6 WORK STATIONS AND MISCELLANEOUS EQUIPMENT

#### 6.2.6.1 SHOP STOOLS

The shop stools selected are the type of shop stool used throughout SPS. Since this is an item that has undergone some recent procurement activity, it has been established that United provides the best stool for the money. Our price for a United D42L stool without casters and with a cloth seat and back is $100.00 each. 16 stools are required, therefore the total is $1,600.00 plus tax and shipping = $2,000.00

#### 6.2.6.2 WORK BENCHES

The work benches selected are the type most used in SPS's manufacturing areas. They are 3 feet deep by 8 feet long with a wood maple top. There are two types selected, one with a set of drawers on the right side under the working area and and a closed compartment on the left. The second type table is designed with a set of drawers on the left side only. These work benches will be used as an addition to the first type of bench and are planned to be set up at a 90 degree angle to the other, see Figure 7-2 for facility layout. The Stanley/VIDMAR line has been used in the pass because of their versatility and durability and these are the units planned for this facility.

#### 6.2.6.3 TOOL CABINETS

Two tool cabinets are planned. One in support of the CO2 laser unit and one in support of the flow form lathe. Theses cabinets are approximately 3 X 3 X 5 feet high with drawers of varying sizes to accommodate small tooling. Again, Stanley/VIDMAR type was selected because this type is presently used in the factory and most desirable by both shop foremen and technicians.

#### 6.2.6.4 TOOL RACKS

Tool racks planned are to accommodate the tooling in support of the presses and the flow form lathe. These racks are of a heavy duty type that comes in 10 foot sections with 5 shelves and are 12 feet high. The shelves are adjustable on 4 inch centers and are adaptable to add-ons if required. Two units are selected making the rack 40 inches deep by 20 feet long by 12 feet high. SPS has just recently purchased some for our High Bay area and they cost about $1,500 for the two units.

#### 6.2.6.5 TD 40136 TANGENT PRESS

This machine will form the major forming operations of the housing until the flow forming equipment is up an operational. It will also serve as a back-up unit throughout the life of the sheet metal facility. It is a four cylinder press that has reverse drawing capability and will allow coil feed. A Tangent press is the same as a Lagan press.

#### 6.2.6.6 TD 40137 CIRCLE SHEER

This shear will be used to cut a disc out of a flat sheet, a necessary operation to control the forming of some parts. There arc several off the shelf units on the market. One of the better makes is ARYMA.

## 6.3 IMPLEMENTATION PLAN

### 6.3.1 FACILITY

The area planned for the Precision Metal forming Cell is located at the south end of Sundstrand's Ruffin Road Facility as shown in Figure 6-5. this area is an open area with a temporary roof used for storage. It is planned to close in and complete this area to meet the requirements for the new sheet metal cell.

The new area is being sized to accommodate the planned equipment in support of the IMIP flow forming cell plus addition equipment that would allow Sundstrand to fabricate all sheet metal parts now under contract and planned future needs, reference Figure 6-6. Note, these additional items located in the facility that are not listed in Figure 6-2.

### 6.3.2 EQUIPMENT

A detailed plan for the procurement, installation, and facility build is shown in Figure 6-7. The down payment for all equipment listed is planned for 1991. The facility construction is also planned for 1991. Receipt of equipment and their installation is planned for 1992, such that the facility and equipment will be capable of delivering production units by mid 1992.

### 6.3.3 MANAGEMENT

The Precision Metal Forming Cell operation will be integrated into Sundstrand's existing management structure. As shown in Figure 6-8, the Director of Operations report to the Vice President and General Manager. In turn, as shown in Figure 6-9, the Manager of Components Manufacturing, report to the Director of Operations. Finally, the new facility operation is the responsibility of the Supervisor of Production, Sheet Metal Components, as shown in Figure 6-10. He in turn report to the Manager of Components Manufacturing.

## 6.4 FOLLOW-ON ACTIVITIES

This new facility will provide Sundstrand the capability to produce our products at a significant savings. Some additional benefits will be in support of future programs both in shortened lead times for existing hardware and reduced time for development of new hardware.

As mentioned in Section 6.3 above, with the addition of more capital equipment (less than $1,000,000), all sheet metal parts can be fabricated in-house with higher quality and at a reduced cost.

| PART | | PREVIOUS DESIGN MAKE | PREVIOUS DESIGN BUY | NEW DESIGN MAKE | NEW DESIGN BUY | |
|---|---|---|---|---|---|---|
| 167180-1 | Manifold Bracket | | X | X | | |
| 163241-1 | Exhaust Flange | | X | X | | Part of Diffuser |
| 163211-1 | Drain Elbow | | X | | X | |
| 162910-3 | Outer Case | | X | X | | |
| 162909-1 | Exhaust Diffuser | | X | X | | |
| 162908-2 | Igniter Doubler | | X | X | | |
| 162907-1 | Drain Boss Doubler | | X | X | | |
| 162906-1 | Tube Ftg. Doubler (6) | | X | X | | Part of Case |
| 162905-1 | Forward Flange | | X | X | | Part of Case |
| 100645-1 | Tube Fitting (6) | | X | | X | |
| 100643-1 | Inj. Nut Disc | | X | | | Part of Case |
| 100642-1 | Pin Nut Disc (4) | | X | | | Part of Case |
| 49265-1 | Igniter Plug Boss | | X | | X | |
| 24003-0 | Fitting (2) | | X | | X | |
| 163737-2 | Hex Nut Pin (4) | | X | | X | |
| 163737-4 | Inj. Nut | | X | | X | |
| COMBUSTOR ASSEMBLY | | X | | X | | |

Figure 6-1 Make Or Buy Plan

| ITEM | $ 1991 | $ 1992 |
|---|---|---|
| FLOW FORM LATHE | 675,000 | 1,575,000 |
| CO2 LASER UNIT | 75,000 | 675,000 |
| HYDRAULIC PRESS 100 TONS | 6,000 | 54,000 |
| SHEAR | 5,000 | 45,000 |
| TANGENT PRESS | 40,000 | 360,000 |
| CIRCLE SHEAR | | 70,000 |
| HYDRAULIC PRESS 400 TONS | | 225,000 |
| EQUIPMENT INSTALLATION | | 50,000 |
| TOOL CABINET 3' X 3' X 5' HIGH (2) | | 1,500 |
| TOOL RACK 42" X 20' X 15' HIGH | | 1,500 |
| WORK BENCH (20) | | 14,000 |
| SHOP STOOLS (16) | | 1,000 |
| FACILITY | 150,000 | |
| CONTINGENCY 5% | 47,550 | 153,600 |
| TOTAL | 998,550 | 3,225,600 |

Figure 6-2 Capital Equipment, Precision Metal Forming Cell

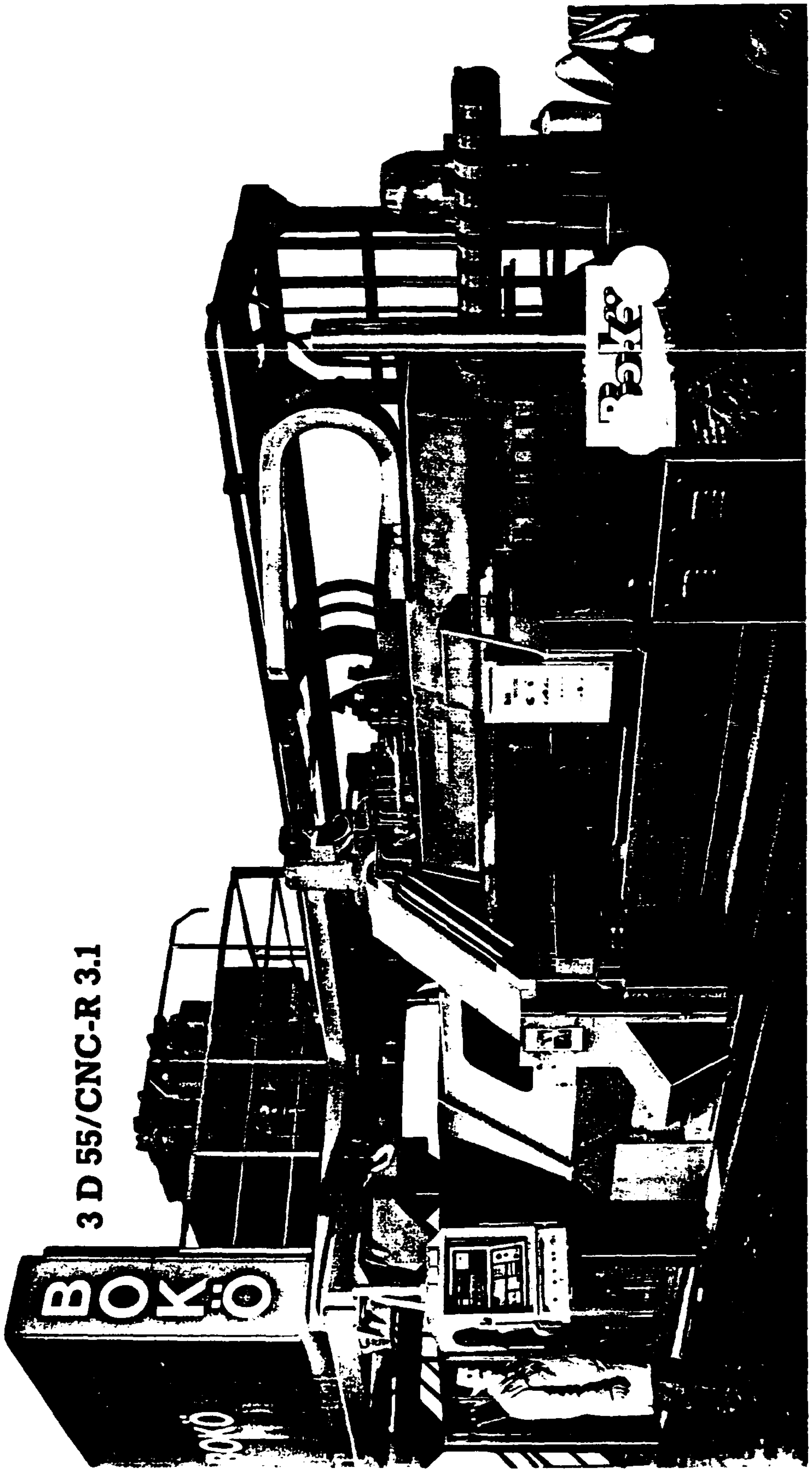



Figure 6-3 Flow Form Lathe

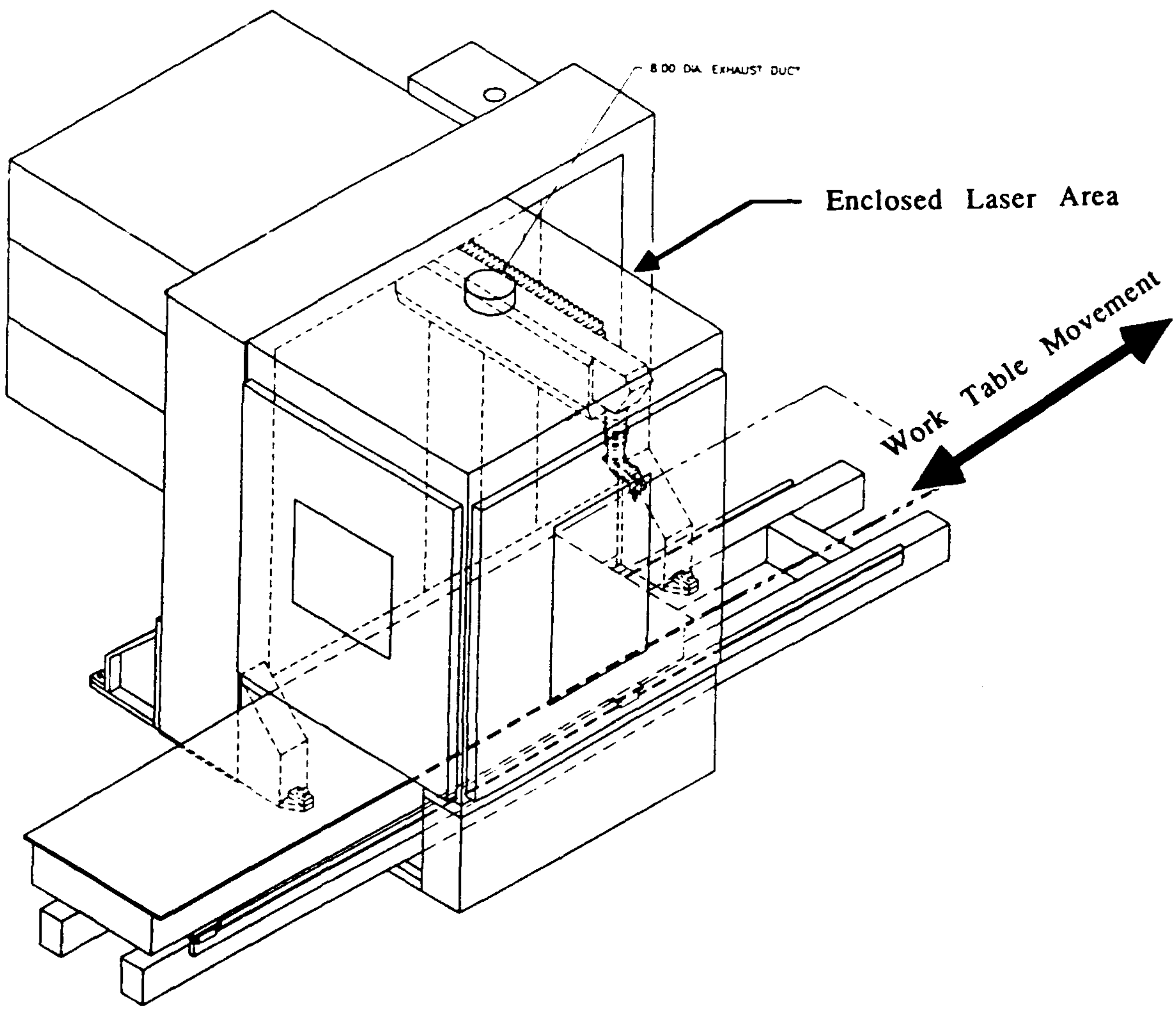
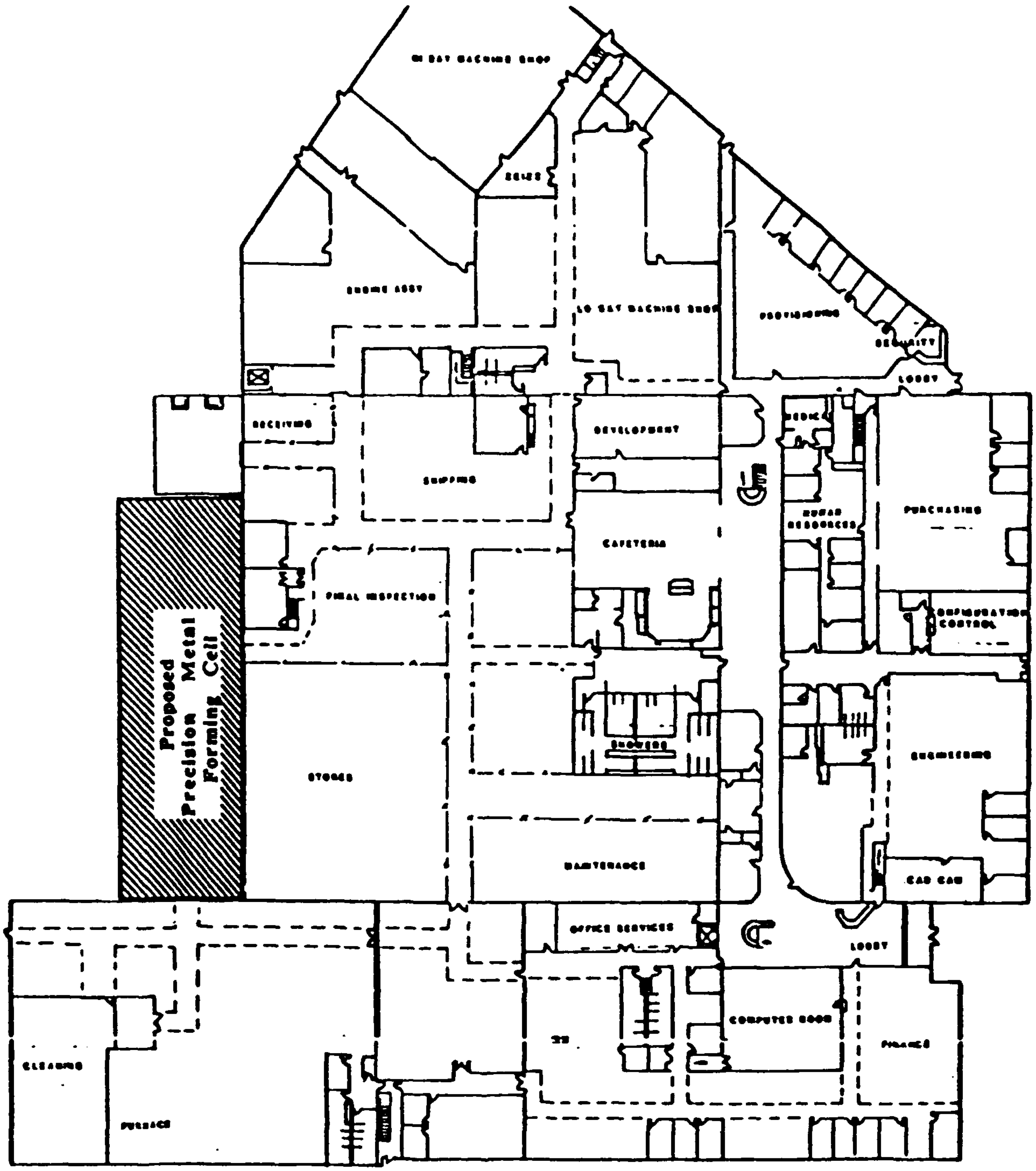



Figure 6-4 CO2 Laser Unit




RUFFIN ROAD FACILITY

Figure 6-5 Location Of The Precision Metal Forming Cell

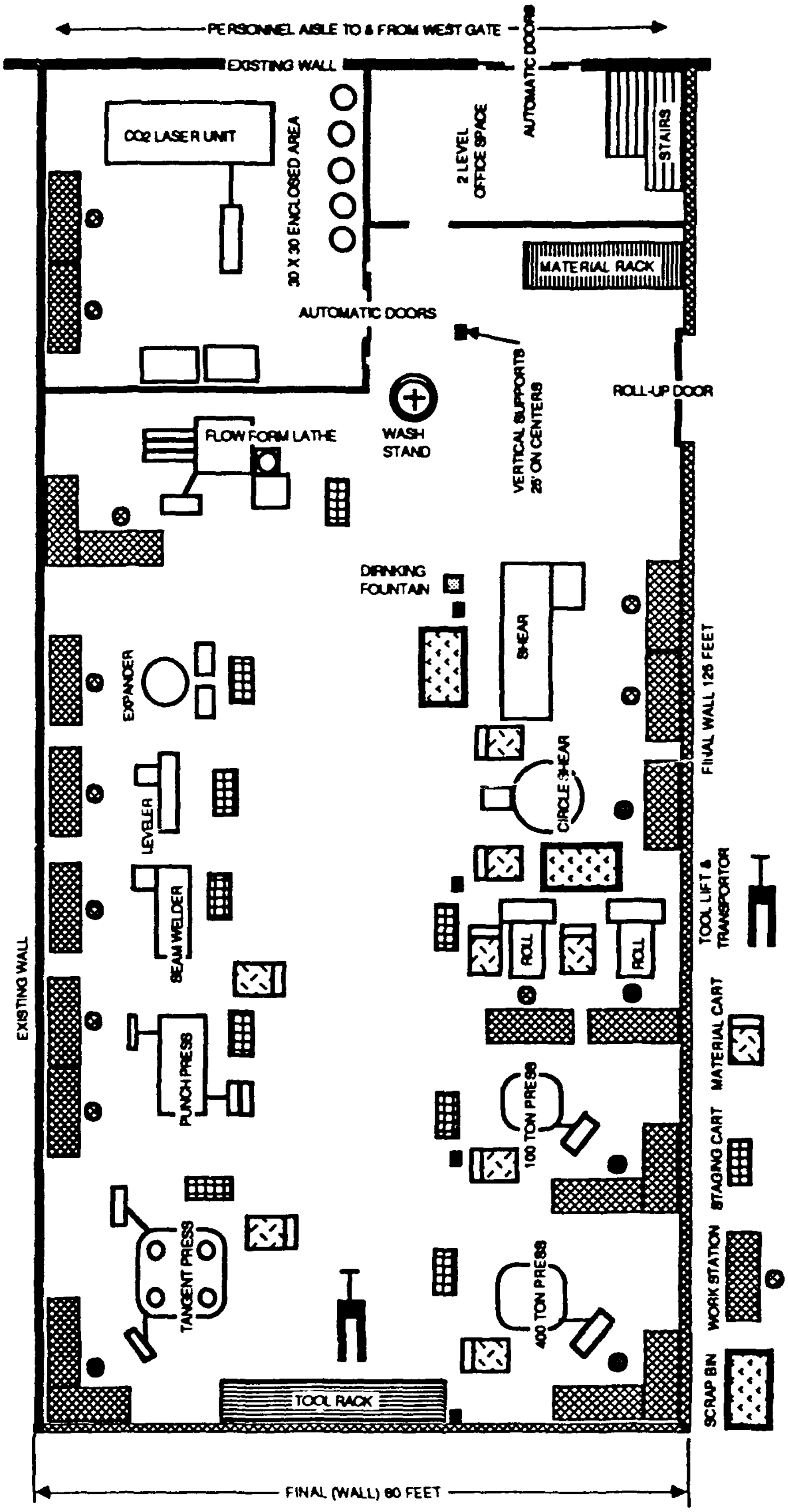



Figure 6-6 Precision Metal Forming Cell Layout

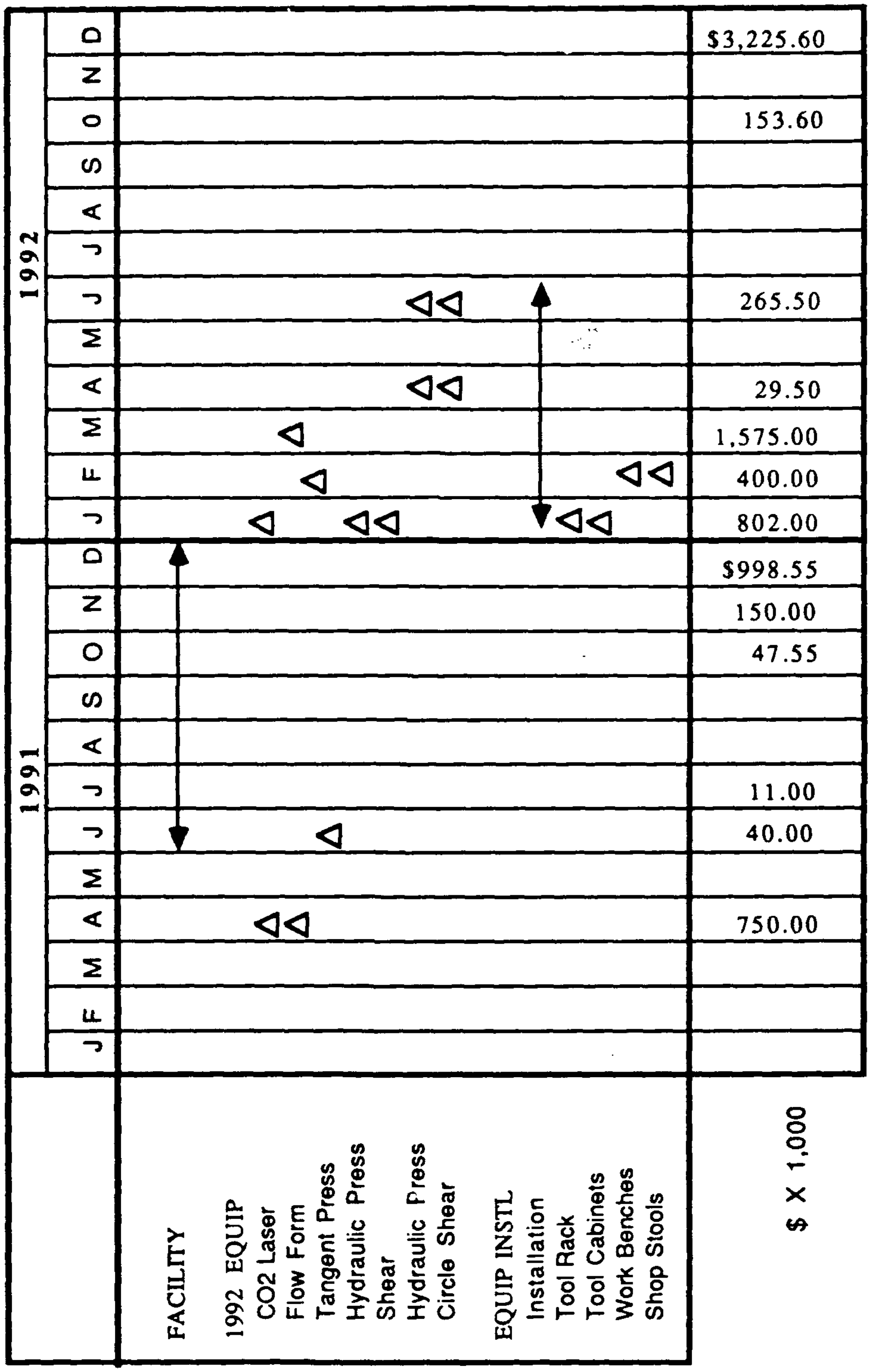



Figure 6-7 Planned Implementation Schedule

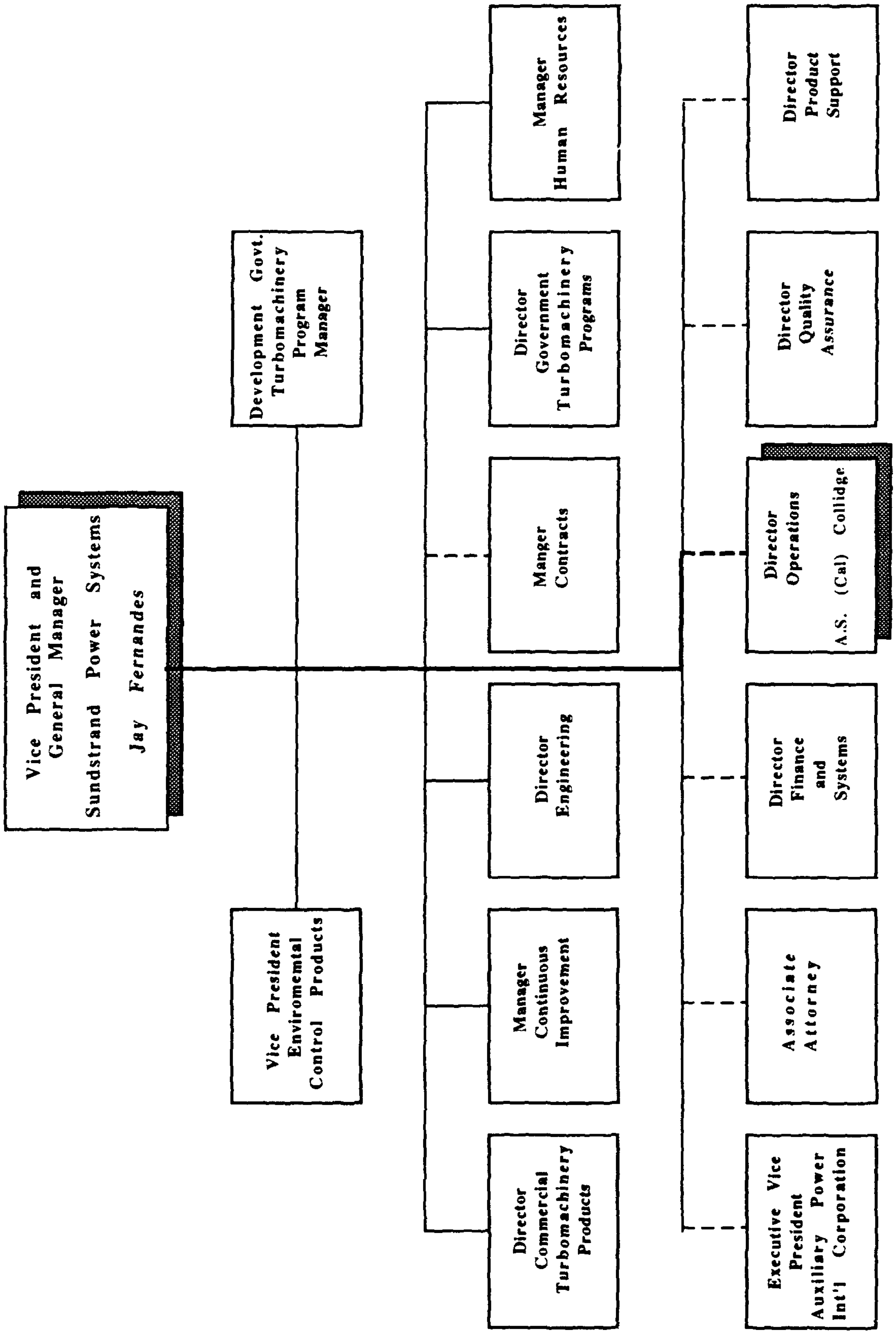



Figure 6-8 Sundstrand Power Systems Management Plan
Precision Metal Forming Cell

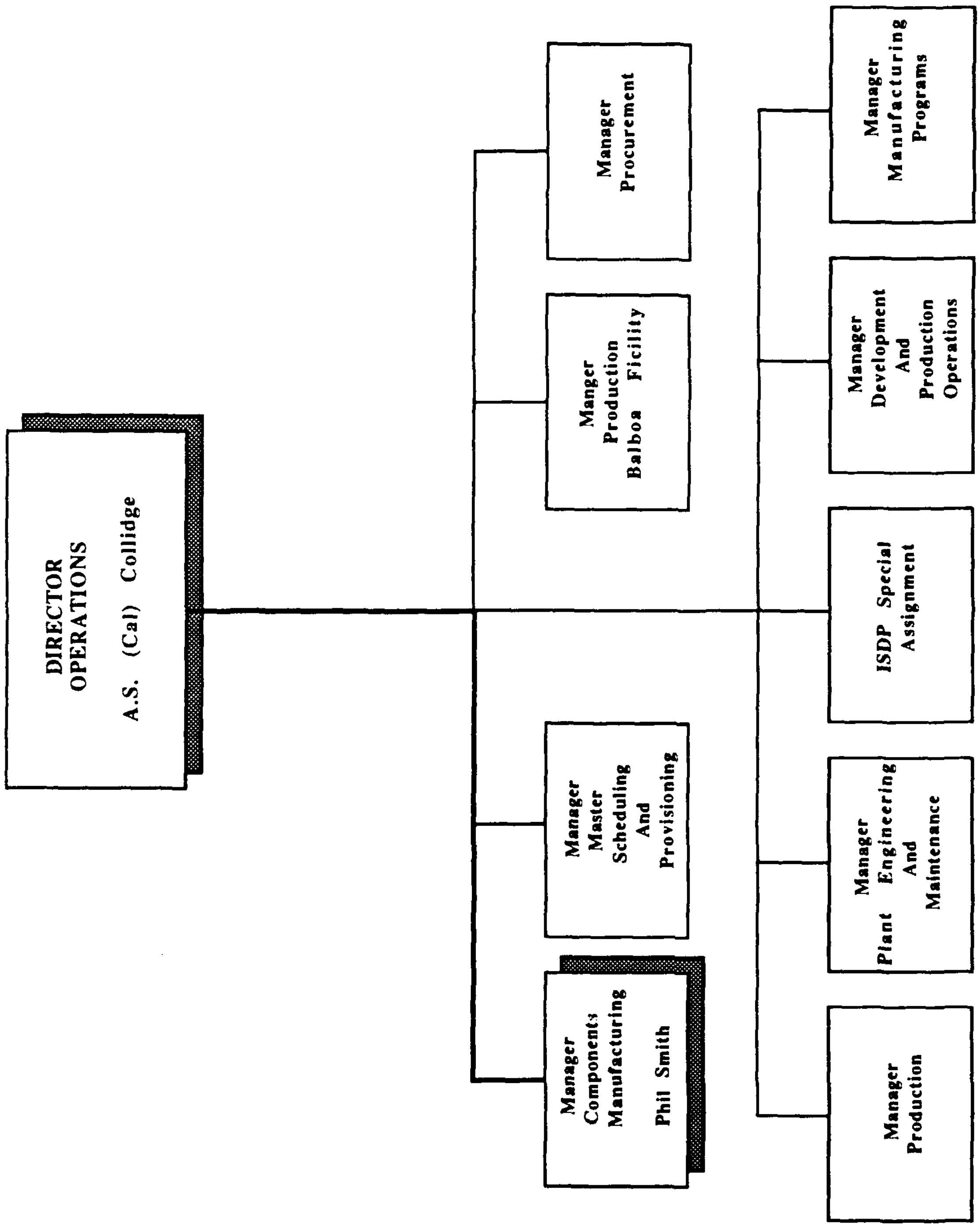



Figure 6-9 Operations Organization - Precision Metal Forming Cell

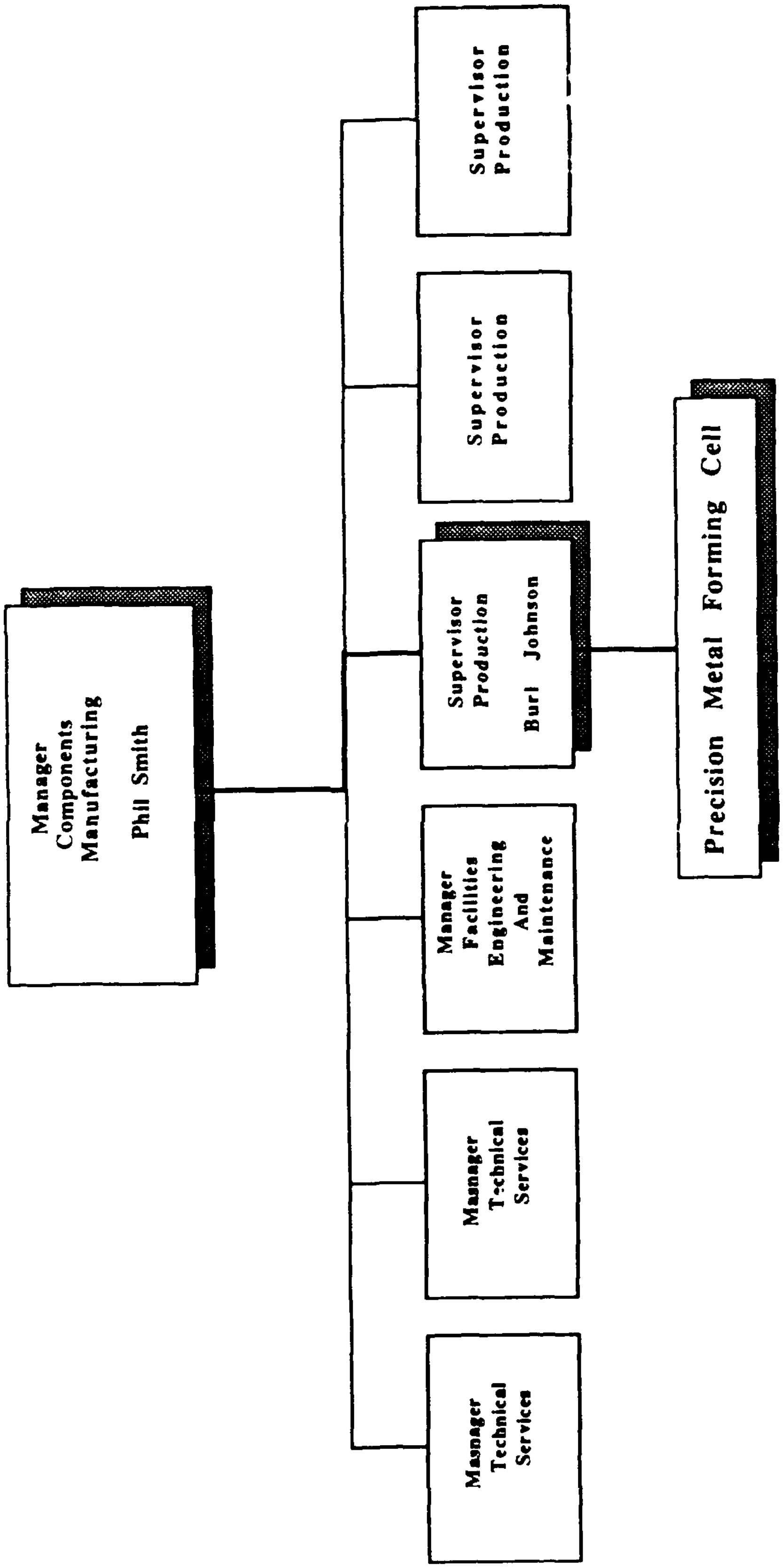



Figure 6-10 Components Manufacturing Organization
Precision Metal Forming Cell

# 7.0 COST BENEFIT ANALYSIS

## 7.1 COST ANALYSIS APPROACH

The basic approach used for the cost analysis update was not the approach used during Phase I. A complete new baseline had to be established due to the many changes in Sundstrand's financial structure since August of 1987, when the Phase I analysis was completed. The Phase I approach was essentially a "grass roots" estimate which would take considerable time and many more hours than planned in the Phase II budget.

The approach used consisted of two parts. First, the Task Node Tree developed in Phase I was updated and was used as the primary guide for developing the cost estimate for nonrecurring effort, see Appendix A.

Second, the primary and recurring task estimate was based upon a detailed analysis of the combustor assemblies as reconfigured. The direct manhours and direct material dollars were estimated and compared to the "AS IS" resulting in the delta direct manhours and dollars per unit. These costs were multiplied by the number of production units planned for the base, year 1990. Sundstrand's 1990 forward pricing rates were applied and distributed in accordance with existing ratios to establish the total cost "TO BE" for the base year.

The base year was then projected through 1998, based upon planned and forecasted production deliveries with the appropriate inflation factors applied, see Figure 7-1. The spike in Commercial units for 1992 is due to the one time retro fit of the 737 with the APS 2000. This helps compensate for the dip planned in Military units that same year. Since the overall production delivery rates are rather consistent, it was determined that the 1990 forward rate ratios would be also fairly consistent.

Finally, the nonrecurring labor and capital equipment planned for this project were added to the forecast in the years that those expenses are expected to occur.

## 7.2 COST BENEFIT SUMMARY

The cost benefit was established for Commercial and Military projects based upon planned and forecasted production deliveries. Only the capital equipment identified in the Phase II plan (flow form and laser weld equipment, military portion) was applied to the Military cost savings. Both the flow form and laser weld equipment (commercial portion) plus the additional capital equipment required for the complete metal forming cell were applied to the Commercial cost savings.

The total accumulated savings forecasted through 1998 are $8,916,450. Commercial savings projected are $4,075,476. Military savings projected are $4,840,974. The savings on the Military side are to be shared between the Air Force and Sundstrand on a 50/50 basis. A summary of the projected savings are shown in Figure 7-2.

## 7.3 RETURN ON INVESTMENT

The government has invested a total of $1,671,647 in the IMIP Phase I and Phase II funded studies. It is projected that with the implementation of the flow forming and laser welding equipment the government will see a savings of $2,420487 over the next seven years. This equates to an average of 20.69% per year return on investment.

Sundstrand Power Systems plans a capital investment of $4,224,150 with a projected savings of $6,495,963 in combustor housing costs for both Commercial and Military programs over the next seven years. This equates to an average of 21.97% per year return on investment.

THE SAVINGS LISTED ABOVE ARE THOSE SAVINGS REALIZED OVER AND ABOVE THE COST OF THE CAPITAL INVESTMENT.

## 7.4 GROUND RULES AND ASSUMPTIONS

7.4.1 All combustor housing assemblies will be of the new configuration in time to support all deliveries planned for 1992.

7.4.2 Configurations other than that used for KC-135 and T-40 assemblies will be accomplished in order of priority based upon production delivery rates. The highest number of deliveries being first.

7.4.3 Flow form and laser weld equipment will be placed on order (contract) in time to support mid 1992 deliveries.

7.4.4 A 10% down payment will be made with each equipment order and all will occur in 1991.

7.4.5 The T-40 and KC-135 combustor housing assemblies will be used as the basis for the detailed cost analysis to determine the direct labor and material dollar impact due to the flow form design.

7.4.6 The cost impact between Q.C. and P.Q.E. will be a wash between the existing and planned configurations.

7.4.7 The cost impact within the Finance departments will be a wash between the existing and planned configurations.

7.4.8 All capital equipment other than that specified in the IMIP Phase I and II plan will be charged against the Commercial Programs only.

7.4.9 The ratios between department functions will remain steady through 1998.

7.4.10 Inflation will occur at a rate of 5% per year through 1998.

## 7.5 BASELINE DEVELOPMENT

The Price Waterhouse software program ACBG was used to establish the "AS IS" baseline. Reference IMIP Phase II Book 4, User Documentation (located at Sundstrand).

7.5.1 To use the ACBG program it necessary to have a TECHMOD Serial Port Security Key installed in the 9 pin Serial Port located on the aft side of the computer. The key consists of a 25 pin connector assembly attached to an adaptor harness with a 25 pin connector to a 9 pin connector.

> Note: If the security key is not already installed onto computer, the key will be stored in the Users Documentation Manual, IMIP Phase II Book 4.

7.5.2 Program call up is: \IMIP\DCF\ACBG\REV. (all caps must be used). The program will request: "YOUR ACCOUNT PLEASE", which is "TECHMOD" (caps).

ENTER PASSWORD "PW" (for Price Waterhouse)

2-1

COMPANY CODE STC Sundstrand Turbomach Corporation - Phase I

SPS Sundstrand Power Systems - Phase II

7.5.3 Once into the ACBG\REV program, a new company SPS was created the same as STC with updated revisions. First the Cost Centers and their expenditures were updated to reflect todays financial structure and expenditures for the period of January 1, 1990 through August 30, 1990. Data was obtained from the Budget Variance Report, etc. See Figure 7-4, Basic 18 Cost Elements. This report specifies the cost element and from which report the data was obtained. See APPENDIX B for detailed cost data by Cost Center for all Cost Centers.

7.5.4 After completion of the Cost Center update was completed, a "Ao" Report was requested form the ACBG\REV program. This report summarizes the Cost Center data in the basic Cost Elements, see Figure 7-5, for above expenditure period. This was then extended thorough the end of 1990, giving us our "AS IS" Base Year.

7.5.5 The "AS IS" and the "TO BE" baseline data were entered into a Lotus Spread Sheet (IMIP-2). The "TO BE" baseline was created by performing a detailed analysis of the T-40 and KC-135 Combustor Housing Assemblies. This analysis was performed by Manufacturing Engineering and the results are shown in Figure 7-6. This analysis provided the change in Direct Labor hours and Direct Material dollars between the existing configuration and the new. Using Sundstrand's Forward Pricing Rates, shown in Figure 7-7, the cost data was entered into the IMIP-2 Cost Benefit Analysis and provided the "TO BE" baseline data. Math for the generation of the "TO BE" baseline and extension through 1998 is shown in Section 7.8.1.2.

## 7.6 NODE TREE UPDATE

7.6.1 The Task Node Tree established in IMIP Phase I study was updated and distributed to all departments affected for comment. All comments were collected and incorporated into its final form shown in APPENDIX A.

7.6.2 The final Node Tree was distributed to all functions affected and used as a guide to determine nonrecurring expenditures required to implement the new Precision Metal Forming Cell. Per Ground Rules and Assumptions all nonrecurring tasks will be complete by the end of 1992. These costs were added into the Cost Benefit Analysis Spread Sheet. Only two departments could identify any significant impact and they were Manufacturing Engineering and ILS. These costs were added to the Direct Nontouch Labor in 1992. Back-up data for this is located in the IMIP Phase II Book 2, located at Sundstrand.

## 7.7 UNIT DELIVERY FORECAST

7.7.1 The basis for Unit Delivery Forecast was the October Plan generated by all Program Offices. The Commercial Data was reviewed by Mr. Rich Pozzi on 8-14-90 and was modified to reflect the SAAB and APS 3000 programs and a forecast of the APS 2000 program out years. Using the above data, a Mean Data Curve was generated establishing the final projected Unit Delivery Forecast, see Figure 7-1. Reference IMIP Phase II Book 2 for detailed back-up data.

## 7.8 DETAILED COST ANALYSIS

### 7.8.1 LOTUS INPUT FORMULAS

All worksheet math is recorded in detail in the IMIP Phase II Reference Book 2, in Section "Impact Raiional". A summary is provided in the following sections.

#### 7.8.1.1 BASIC DISTRIBUTION

The basic distribution of dollars was based upon the *existing ratios between* basic elements of the base year, reference Figure 7-2. It was assumed that these ratios will remain constant for the period of this analysis. They are:

| | | $ | RATIO |
|---|---|---|---|
| Direct Labor Burden | | | |
| Indirect Touch Labor | | 454,976 | .83333 |
| Indirect Nontouch Labor (.1737) | | 2,850,984 | .52222 |
| Rework Labor | | 319,232 | .05847 |
| Maintenance (.1737) | | 21,917 | .00401 |
| Supplies (.1737) | | 75,803 | .01388 |
| Tooling | | 394,374 | .07224 |
| Facilities (.1737) | | 113,367 | .02077 |
| Utilities | | 995,296 | .18231 |
| Miscellaneous (.1737) | | 233,433 | .04277 |
| | TOTAL | 5,459,382 | 1.00000 |
| Material Burden | | | |
| Indirect Nontouch Labor (.8263) | | 13,562,280 | .58885 |
| Outside Services | | 5,394,690 | .23423 |
| Maintenance (.8263) | | 104,262 | .00453 |
| Supplies | | 360,601 | .01566 |
| Information Systems | | 175,686 | .00763 |
| Facilities (.826 | | 539,291 | .02342 |
| Travel | | 1,784,250 | .07747 |
| Miscellaneous (,8363) | | 1,110,453 | .04821 |
| | TOTAL | 23,031,513 | 1.00000 |

7.8.1.2 BASE YEAR EXTENSION

The base year was extended through 1997 based upon the production/delivery rates and inflation forecast. The APS 2000 Combustor Housing costs are 2.3 times the cost of the other housings, therefore an adjustment to the quantity delivered was added to compensate for both cost of the APS 2000 and to provide a proper mix between Military and Commercial savings. The above rates and factors used, are shown below:

| | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|
| Delivery Rate | 936 | 818 | 808 | 943 |
| APS 2000 Adjustment to Prod. | 9 | 127 | 343 | 193 |
| Inflation Rate | 1.0 | 1.0500 | 1.1025 | 1.1576 |
| Extension Factor | 1.0 | 1.0500 | 1.3428 | 1.3916 |

| | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|
| Delivery Rate | 780 | 740 | 700 | 660 | 620 |
| APS 2000 Adjustment to Prod. | 136 | 136 | 136 | 136 | 136 |
| Inflation Rate | 1.2155 | 1.2763 | 1.3401 | 1.4071 | 1.4775 |
| Extension Factor | 1.1666 | 1.1561 | 1.1572 | 1.1361 | 1.1507 |

For example the Extension Factor for the year 1992 = 1.3428. This is obtained by establishing a ratio between the Base Year (1990) and the year 1992 for the number of production or planned delivery units for that year. To neutralize the expensive APS 2000 Housings which costs 2.3 times as much as the other units, an Adjustment Factor was added.

The Adjustment Factor is established by obtaining the number of APS 2000 units planned for a given year and multiplying by the cost factor of 2.3 - the number of APS 2000 housings in the total year. Using 1992, the total number of Production Units = 808. Of the 808 total units, 264 are APS 2000 units. Therefore, 264 X 2.3 = 607. Since there are 264 APS 2000 units already in the 808 count, 264 is removed from the 607 above to give the total Adjustment Factor = 343.

Since the Adjustment Factor for 1990 (calculated the same way) = 9, the total number of production units for 1990 is 936 + 9 or 945. Comparing the total number of production units for 1992 (808 + 343 or 1151) to 1990 (945), the Extension Factor becomes 1151/945 = 1.2180. By adding the inflation rate of 5% per year (1992 = 1.1025) the final Extension Factor = 1.2180 X 1.1025 = 1.3428.

For 1993 the Extension Factor = 943 + 193/(936 +9) X 1.1576 = 1.3916.

7.8.1.3 COMMERCIAL AND MILITARY SPLIT

The split in savings, cost of capital equipment and depreciation of that equipment between Commercial and Military projects was based upon their ratio of delivered units each year. The ratios used for this analysis are:

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| Commercial | .1852 | .3471 | .6202 | .4129 | .4377 | .4860 | .5343 | .5872 | .6195 |
| Military | .8148 | .6529 | .3798 | .5871 | .5623 | .5140 | .4657 | .4128 | .3805 |

Results of this split between Commercial and Military projects is shown in Figure 7-2.

7.8.1.4 CAPITAL EQUIPMENT

The split in capital equipment as been separated into two categories: That which is shared between Commercial and Military projects and that which was app;lied to the Commercial projects only, reference Figure 7-3.

This is a direct input into the Cost Work Sheet, reference Figure 7-2. Note, the down payment for the capital equipment is in 1991. The balance will occur in 1992 when the equipment is received. The new facility has been estimated to cost $150,000. To insure that all costs have been considered, a 5% contingency was also added for 1991 and 1992. Sundstrand's planned expenditure schedule is shown in Figure 7-8.

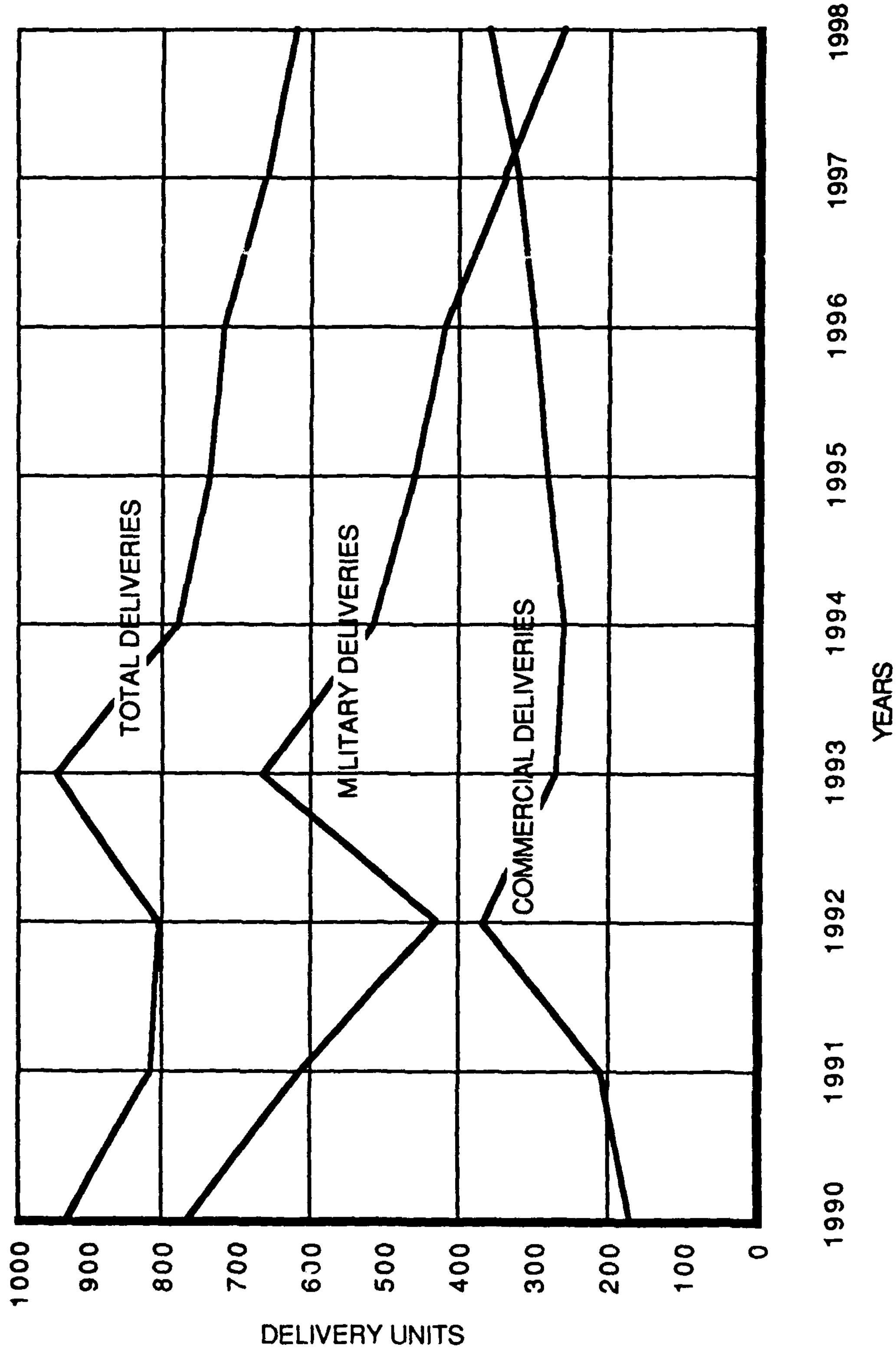



Figure 7-1 Production Delivery Forecast

SUNDSTRAND POWER SYSTEMS — COST BENEFIT ANALYSIS - COMBUSTOR HOUSING ASSEMBLY — 01:14:06 PM

FILE: IMIP-2-7.WK1 — IMIP - PRECISION METAL FORMING CELL — 08-Mar-91

| COST ELEMENT | | BASE YR 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SUMMARY | | | | | | | | | | | |
| PROJECT TOTAL | "AS IS" | 89,880,432 | 94,374,454 | 120,376,863 | 125,077,609 | 104,854,512 | 103,910,767 | 104,009,636 | 102,113,159 | 103,425,413 | 858,142,413 |
| | "TO BE" | 88,706,506 | 94,409,454 | 119,706,995 | 123,443,974 | 103,485,010 | 102,553,592 | 102,651,169 | 100,779,462 | 102,074,577 | 849,104,234 |
| POT SAV PROJ SUB TOTAL | | 1,173,926 | 0 | 669,867 | 1,633,635 | 1,369,502 | 1,357,175 | 1,358,467 | 1,333,697 | 1,350,836 | 9,073,178 |
| G & A | | 262,138 | 0 | 149,581 | 364,791 | 305,810 | 303,057 | 303,346 | 297,814 | 301,642 | 2,026,041 |
| POT SAV PROJ SUB TOTAL | | 1,436,063 | 0 | 819,449 | 1,998,425 | 1,675,311 | 1,660,233 | 1,661,812 | 1,631,511 | 1,652,478 | 11,099,219 |
| COMMERCIAL SAVINGS | | 0 | 0 | 508,222 | 825,150 | 733,284 | 806,873 | 887,906 | 958,023 | 1,023,710 | 5,743,168 |
| FLOW FORM EQUIPMENT | | 0 | (260,325) | (1,395,450) | 0 | 0 | 0 | 0 | 0 | 0 | (1,655,775) |
| EQUIPMENT DEPRICATION | | 0 | 0 | 84,498 | 56,255 | 59,633 | 66,214 | 72,795 | 80,002 | 84,402 | 503,799 |
| ADDITIONAL CELL EQUIP | | 0 | (248,550) | (975,600) | 0 | 0 | 0 | 0 | 0 | 0 | (1,224,150) |
| EQUIPMENT DEPRICATION | | 0 | 0 | 55,594 | | | | | | | |
| COST OF MONEY | | 0 | (43,254) | (146,433) | 79,645 | 72,123 | 78,938 | 86,385 | 92,958 | 98,915 | 319,277 |
| TOTAL COMMERCIAL SAVINGS | | 0 | (552,129) | (1,869,169) | 1,016,643 | 920,635 | 1,007,619 | 1,102,680 | 1,186,577 | 1,262,621 | 4,075,476 |
| MILITARY SAVINGS | | 0 | 0 | 311,227 | 1,173,276 | 942,027 | 853,360 | 773,906 | 673,488 | 628,768 | 5,356,051 |
| FLOW FORM EQUIPMENT | | 0 | (489,675) | (854,550) | 0 | 0 | 0 | 0 | 0 | 0 | (1,344,225) |
| EQUIPMENT DEPRICATION | | 0 | 0 | 51,745 | 79,988 | 76,609 | 70,029 | 63,448 | 56,241 | 51,840 | 449,901 |
| COST OF MONEY | | 0 | (41,622) | (41,784) | 106,527 | 86,584 | 78,488 | 71,175 | 62,027 | 57,852 | 379,247 |
| TOTAL MILITARY SAVINGS | | 0 | (531,297) | (533,363) | 1,359,791 | 1,105,221 | 1,001,876 | 908,529 | 791,756 | 738,460 | 4,840,974 |
| TOTAL POTENTIAL SAVINGS | | 0 | (1,083,427) | (2,402,531) | 2,376,434 | 2,025,856 | 2,009,495 | 2,011,209 | 1,978,333 | 2,001,081 | 8,916,450 |

RETURN ON INVESTMENT BASED UPON A 50-50 SHARE ON MILITARY PROGRAM SAVINGS

AIR FORCE SAVINGS = 2,420,487 WITH AN INVESTMENT OF 1,671,647 THE IRR OVER THE SEVEN YEARS ABOVE = 20.69 %

SUNDSTRAND SAVINGS = 6,495,963 WITH AN INVESTMENT OF 4,224,150 THE IRR OVER THE SEVEN YEARS ABOVE = 21.97 %

Figure 7-2 Summary, Projected Cost Savings

| ITEM | $ 1991 | $ 1992 | $ TOTAL |
|---|---|---|---|
| * FLOW FORM LATHE | 675,000 | 1,575,000 | 2,250,000 |
| * CO2 LASER UNIT | 75,000 | 675,000 | 750,000 |
| HYDRAULIC PRESS 100 TONS | 6,000 | 54,000 | 60,000 |
| SHEAR | 5,000 | 45,000 | 50,000 |
| TANGENT PRESS | 40,000 | 360,000 | 400,000 |
| CIRCLE SHEAR | | 70,000 | 70,000 |
| HYDRAULIC PRESS 400 TONS | | 225,000 | 225,000 |
| EQUIPMENT INSTALLATION | | 50,000 | 50,000 |
| TOOL CABINET 3' X 3' X 5' HIGH (2) | | 1,500 | 1,500 |
| TOOL RACK 42" X 20' X 15' HIGH | | 1,500 | 1,500 |
| WORK BENCH (20) | | 14,000 | 14,000 |
| SHOP STOOLS (16) | | 1,000 | 1,000 |
| FACILITY | 150,000 | | 150,000 |
| CONTINGENCY 5% | 47,550 | 153,600 | 201,150 |
| TOTAL | 998,550 | 3,225,600 | 4,224,150 |

* Equipment identified in IMIP Phase II plan chagred against military contracts.

Figure 7-3 Listing Of Capital Equipment Planned In Support Of The Precision Metal Forming Cell

| Cost Element | Data Source |
|---|---|
| Direct Touch Labor | Budget Varience Report |
| Indirect Touch Labor | Budget Varience Report |
| Direct Nontouch Labor | Budget Varience Report |
| Indirect Nontouch Labor | Budget Varience Report |
| Rework Labor | Quality Assurance Report |
| Outside Services | Budget Varience Report |
| Maintenance | Budget Varience Report |
| Scrap | Quality Assurance Report |
| Supplies | Budget Varience Report |
| Information Systems | Budget Varience Report |
| Equipment | Budget Varience Report |
| Tooling | Budget Varience Report |
| Facilities | Budget Varience Report |
| Utilities | Budget Varience Report |
| Material | P. O. Commmit Report |
| Travel | Budget Varience Report |
| Miscellaneous | Budget Varience Report |

Figure 7-4 Sundstrand Basic Cost Elements

SUNDSTRAND POWER SYSTEMS

Ao REPORT
ALL COST CENTERS SELECTED

| Included Cost Elements: | Costs 6 Month Base Year | Costs 12 Month Base Year |
|---|---|---|
| DIRECT TOUCH LABOR | 2,977,923 | 5,955,846 |
| INDIRECT TOUCH LABOR | 227,488 | 454,976 |
| DIRECT NONTOUCH LABOR | 7,836,297 | 15,672,594 |
| INDIRECT NONTOUCH LABOR | 8,206,632 | 16,413,264 |
| REWORK LABOR | 159,616 | 319,232 |
| OUTSIDE SERVICES | 2,697,345 | 5,394,690 |
| MAINTENANCE | 63,090 | 126,180 |
| SCRAP | 732,300 | 1,464,600 |
| INVENTORY CARRYG COST | NOT USED | NOT USED |
| SUPPLIES | 218,202 | 436,404 |
| INFORMATION SYSTEMS | 87,843 | 175,686 |
| EQUIPMENT | 2,007,984 | 4,015,968 |
| TOOLING | 197,187 | 394,374 |
| FACILITIES | 326,329 | 652,658 |
| UTILITIES | 497,648 | 995,296 |
| MATERIAL | 17,140,264 | 34,280,528 |
| TRAVEL | 892,125 | 1,784,250 |
| MISCELLANEOUS | 671,943 | 1,343,886 |
| TOTAL: | 44,940,216 | 89,880,432 |

Figure 7-5 Ao Report

160007 (T40-8) 161637 (KC-135)
Combustor Assembly Cost Analysis

| PART NUMBER/NAME | | CURRENT | PROPOSED | COMMENTS |
|---|---|---|---|---|
| 167180-1 | MANIFOLD BRKT. | $ 15.99 | $ 15.99 | SAME |
| 163214-1 | EXHAUST FLANGE | $ 70.99 | 0 | PART OF DIFFUSER |
| 163211-1 | DRAIN ELBOW | $ 18.04 | $ 18.04 | SAME |
| 162910-3 | OUTER CASE | $352.25 | $ 45.00 | FLOW FORMED |
| 162909-1 | EXHAUST DIFFUSER | $126.48 | $ 25.00 | FLOW FORMED |
| 162908-2 | IGNITER DOUBLER | $ 15.05 | $ 1.50 | MODIFIED |
| 162907-1 | DRAIN BOSS DOUBLER | $ 9.89 | $ 3.00 | MODIFIED |
| 162906-1 | TUBE FTG. DBLR. (6) | $ 63.72 | $ 0 | PART OF OUTER CASE |
| 162905-1 | FORWARD FLANGE | $ 46.36 | $ 0 | PART OF OUTER CASE |
| 100645-1 | TUBE FTG. (6) | $ 25.32 | $ 95.70 | MODIFIED |
| 100643-1 | INJ. NUT DISC. | $ 2.60 | $ 0 | PART OF OUTER CASE |
| 100642-1 | PIN NUT DISC (4) | $ 13.00 | $ 0 | PART OF CASE |
| 49265-1 | IGN. PLUG BOSS | $ 3.54 | $ 3.54 | SAME |
| 24003-0 | FITTING (2) | $ 53.82 | $ 8.40 | MODIFIED |
| 163737-2 | HEX NUT PIN (4) | $ 12.28 | $ 14.16 | MODIFIED |
| 163737-4 | INJ. NUT | $ 3.29 | $ 4.40 | MODIFIED |
| | TOTAL MATERIAL | $832.62 | $234.73 | SAVINGS = $597.89 |
| IN-HOUSE FABRICATION | | | | |
| 162910-3 | OUTER CASE | 0.00 | .40 HRS. | |
| 162909-1 | EXHAUST DIFFUSER | 0.00 | .20 HRS. | |
| 162908-2 | IGNITER DOUBLER | 0.00 | .04 HRS. | |
| 162907-1 | DRAIN BOSS DOUBLER | 0.00 | .08 HRS. | |
| COMBUSTOR ASSEMBLY | | 10.34 HRS | 5.20 HRS | |
| | TOTAL FAB. HOURS | 10.34 | 5.92 | SAVINGS = 4.42 HRS. |

Figure 7-6 Unit Cost Analysis

| ITEM | 1990 | 1991 | ITEM | 1990 |
|---|---|---|---|---|
| Material | 15,74% | 16.50% | G & A | 22.8% |
| Scrap | 4.00% | 4.00% | Treasury | 8.5% |
| Manufacturing | $14.28 | $14.99 | | |
| Burden | $89.72 | $94.21 | | |
| Engineering | $22.27 | $23.38 | | |
| Burden | $27.04 | $28.39 | | |

Figure 7-7 Forward Pricing Rates

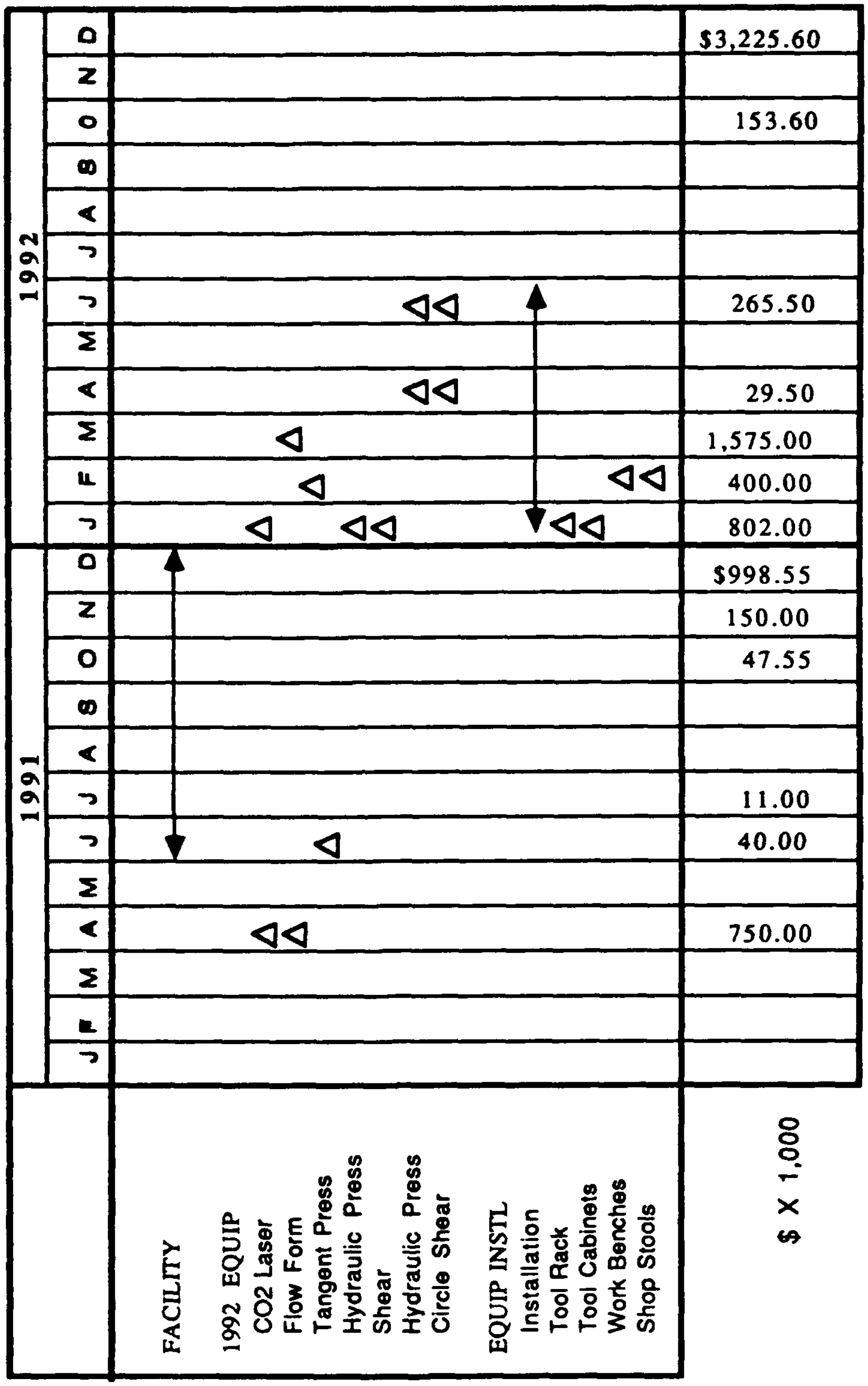



Figure 7-8 Schedule Of Capital Expenditures

# 8.0 COST/SAVINGS RISK ANALYSIS

The Cost/Benefit Analysis in Section 7.0 was accomplished by taking a very conservative approach to projected savings. The elements of risk associated with the implementation of the Precision Metal Forming Cell are:

1. Projected sales or number of units planned for delivery
2. Cost of capital equipment/facilities
3. Part fabrication costs
4. Material costs
5. Recurring/Nonrecurring effort is support of the new facility
6. Other costs

## 8.1 PROJECTED SALES

The projected sales shown in Section 7.0, Figure 7-1, are based upon firm sales, near term sales, and likely sales thru 1998. This projection shows a continuous reduction in sales, which is a worst case scenario. Once the new facility is in place, it is expected that sales will increase due to a reduction in product cost and the ability to expand Sundstrand's product base.

## 8.2 COST OF CAPITAL EQUIPMENT/FACILITIES

All costs for capital equipment were from actual quotes or estimates based upon the highest quotes of similar equipment. Experience shows that minor costs will occur for items inadvertently overlooked. Therefore, a percent contingency factor ($201,150) was added. It is expected that another 2 to 3 percent can be obtained during negotiations for the procurement of the equipment. Costs associated with the building of the facility are well known and it is expected that the economy in 1991 will not change enough to drive costs above that estimated.

## 8.3 PART FABRICATION COSTS

Manhours and run times used in the development of unit costs were based upon actuals obtained from our vendors now fabricating the combustor components for the IMIP study. As discussed in Section 4.0, there are 9 steps in just the forming of the combustor housing. The cost analysis was based on using this same procedure in house. Once the flow form lathe is operational and technique demonstrated by BOKO is in place, housing costs will greatly decrease. Assembly costs decrease due to the one-piece housing design, which has fewer parts. Estimated assembly times were multiplied by 2 to be conservative, even then a significant reduction can be achieved. In addition, when laser welding is incorporated assembly times will be just a fraction of that experienced with brazing.

## 8.4 MATERIAL COSTS

With the incorporation of the new facility, materials will be mostly limited to raw materials or minor parts presently being fabricated. Both of these costs are well known and a 5 percent inflation factor per year was added. This is higher than being experienced today or projected by economists.

## 8.5 RECURRING/NONRECURRING SUPPORT COSTS

These are costs associated with new tooling and Manufacturing Engineering support for start-up of the new facility and on going facility support. Tooling already exists to support housings fabricated using the method used to fabricate the housings for the IMIP study. Very little tooling will be required for the new flow form lathe. Manhours estimated to develop planning, etc in support of fabrication of parts in-house was increase by 30 percent to allow for unanticipated tasks. No reduction in Manufacturing Engineering support was taken due to fewer parts being procured. It was assumed that the additional liaison support would equal the required support for existing procurement of parts. Experience shows this to be a conservative assumption.

## 8.6 OTHER COSTS

There are other costs savings which can be realized, such as the reduction in material handling and material stores which were not incorporated into the cost/benefit analysis. Material handling costs will be reduced due to the reduction in parts with the new one-piece design. In addition, once the new facility is in operation, Sundstrand will no longer carry the large inventory presently required to support production assembly schedules. *It is planned to produce the flow formed* parts on a "just in time" basis.

## 8.7 RISK ANALYSIS SUMMARY

With the conservative approach taken in the Cost/Benefit analysis, as stated in Sections 8.1 thru 8.6, it is Sundstrand's position that there is very little or no risk associated with achieving the projected cost savings. In fact, it is expected that both the government and Sundstrand will experience greater savings than projected.

APPENDIX A

# SUNDSTRAND POWER SYSTEMS IMIP
# NODE TREE FOR PHASE III

(NODES IMPACTED ARE HIGHLIGHTED IN BOLD TYPE)

Revision: A August 7, 1990

A 1 MARKET AND SELL PRODUCT

**A 2 ADMINISTRATE COMPANY**

A 21 Preform Financial Planning and Analysis

**A 2 2 Perform General Accounting**

**A 2 2 1 MANAGE ASSETS**

- A2211 Account For Cash/Marketable Securities/Prepaid Items
- A2212 Manage Accounts Receivable
- A2213 Manage Notes Receivable
- **A2214 Account For Plant Property and Equipment**
- A2215 Account For Long Term Investments/Receivables

A222 MANAGE LIABILITIES

- A2221 Manage Accounts Payable
- A2222 Account For Notes Payable
- A2223 Account For Taxes Payable
- A2224 Account For Accruals
- A2225 Provide Payroll Processing

**A 2 2 3 MANAGE COSTS**

- **A2231 Account For Standard/Product Costs**
- **A2232 Control Inventory Costs**
- **A2233 Generate Rate Information**
- A2234 Perform Labor Audit Procedures

**A 2 2 4 PREPARE FINANCIAL STATEMENTS/REPORTS**

- A2241 Generate Company Balance Sheet/Income
- **A2242 Generate Product Income Statement**
- **A2243 Analyze and Report On *Operating Various***

A23 Manage **Programs**

A 2 3 1 **PLAN** AND CONTROL PRODUCT ORDERS AND DELIVERIES

A 2 3 2 **ENSURE** CUSTOMER AND TECHNICAL REQUIREMENTS ARE MET

A 2 3 3 **PLAN** PROGRAM BOOKINGS AND REVENUE

**A 2 3 4 DEVELOP AND MONITOR PROGRAM BUDGETS**

A 2 3 5 **ADMINISTER** CONTRACT

- **A2351** Interpret Customer Requirements As Contractulized To Sales Order
- **A2352** Interpret Contract Law & Government Regulations
- A2353 Conduct Formal Interface With Customer Status & Program Updates
- A2354 Ensure All CDRL's Are Met
- A2355 Analyze & Incorporate Contract Revisions/Addenda

A 2 3 6 **MANAGE** PROGRAM TEAM

A24 Provide Information Services

A 2 4 1 **PROVIDE INFORMATION RESOURCE MANAGEMENT (IRM)**

A2411 **Provide Business System Applications**

A24111 Provide Financial Systems

A24112 **Provide Manufacturing Systems**

A241121 **Provide Systems Analysis**

A241122 **Provide Systems Development**

A241123 **Provide Systems Implementation Support**

A241124 **Provide Systems Training To User**

A24113 Provide Payroll-Personnel System

A2412 Provide Office Automation

A2413 Operate Information Center

A2414 Provide Telecommunications

A2415 Provide System Security

A 2 4 2 PROVIDE TECHNICAL SYSTEMS MANAGEMENT

A2421 Provide CAD System & Support (Commercial only)

A2422 Provide CAE System & Support

A2423 **Provide CAM System & Support**

A2424 Provide CAP System & Support

A2425 Provide CIM System & Integrate DEC with CINCOM Mfg. System

A243 OPERATE HOST DEC COMPUTER NETWORK

A25 Manage Human Resources

A26 Provide Facilities/Equipment Engineering & Maintenance

A 2 6 1 **Provide Facilities Design & Engineering**

A 2 6 2 **Perform Equipment Engineering**

A 2 6 3 **Perform Facilities Maintenance**

A 2 6 4 **Perform General Equipment Maintenance**

A 3 ENGINEER PRODUCT

A4 MANUFACTURE PRODUCT

A 4 1 Perform Manufacturing/Industrial Engineering

A 4 1 1 PERFORM SUPPLIER TECHNICAL LIAISON

A 4 1 2 PERFORM INDUSTRIAL ENGINEERING

A4121 **Conduct Work Measurement Analysis**

A4122 **Analyze Manpower Requirements**

A4123 Analyze Potential Applications of New Technologies

A 4 1 3 PERFORM ASSEMBLY & MANUFACTURING ENGINEERING

A4131 **Prepare Process Planning To Accomplish Assy & Mfg. Ops.**

A4132 Create Photo Planning to Assist Assembly Operations

A4133 **Determine Perishable Tools & Hardware to Support Mach. Ops**

A4134 **Program CNC Operations**

A4135 **Provide Welding Engineering Data & Process**

A4136 **Perform Shop Floor Liaison**

A414 PERFORM TEST MANUFACTURING ENGINEERING

A 4 1 5 PERFORM TRAINING FOR SHOP FLOOR & ENGR PERSONNEL

A 4 2 **<u>Plan Schedule and Control Production</u>**

A 4 2 1 CREATE MASTER SCHEDULE

A 4 2 1 1 Review Production Unit Forecast

A4212 Coordinate With Program Management

A 4 2 1 3 Refine Production Unit Forecast Into Master Schedule

A 4 2 2 DETERMINE REQUIREMENTS & RELEASE ORDERS

A 4 2 2 1 Determine & Analyze Production & Material Requirements

A 4 2 2 2 Release Purchase Requisitions

A 4 2 2 3 Release Work Orders

A 4 2 3 CONTROL SHOP FLOOR

A 4 2 3 1 Schedule Daily Build Activity

A 4 2 3 1 1 Determine Priorities & Release W/O's For Kitting

A 4 2 3 1 2 Determine Available Material

A 4 2 3 1 3 Provide Work Assignments & Routing To Mechs.

A 4 2 3 2 Supervise Mechanics, Test tech, & Material Movers

A 4 2 3 3 Resolve Inventory/Work Order Discrepancies

A 4 2 3 3 1 Research Various Quality, Inventory, History, Req's

A 4 2 3 3 2 Interface With Involved Individuals

A 4 2 3 3 3 Determine Inventory Adjustments/Resolutions

A 4 2 3 3 4 Resolve Work Order Problems

A 4 2 3 4 Expedite Material

A 4 2 3 4 1 Prioritize Parts According To Shortages & Need

A 4 2 3 4 2 Analyze Past-Due MRP Req'mts & Up-Date

A 4 2 3 4 3 Ensure Parts Are Located & Issued To Floor

A 4 2 3 5 Monitor Production Line & Paper Flow

A 4 3 **<u>Engineer Quality</u>**

A 4 3 1 ASSURE QUALITY OF OUTSIDE PRODUCED HARDWARE

A 4 3 1 1 Monitor Vendors & Assure Quality Compliance

A 4 3 1 1 1 Survey Vendor For Acceptable Quality Standards

A 4 3 1 1 2 Rate Vendor Performance & Update Vendor Rating

A 4 3 1 1 3 Audit Vendors For Compliance To Specifications

A 4 3 1 1 4 Conduct Vendor Source Inspection

A 4 3 1 2 Review & Approve All Special Processes

A 4 3 1 3 Determine Purchase Order Quality Requirements

A 4 3 1 4 Prepare Detail Check Charts For Receiving Inspection

A 4 3 1 5 Conduct Receiving Inspection

A 4 3 1 5 1 Conduct Mech. Insp. on Outside Hardware & Tools

A43152 Conduct Electrical Inspection

A 4 3 1 5 3 Inspect Raw Material

A 4 3 2 ASSURE QUALITY OF IN-HOUSE PRODUCT

A4321 Review Contracts & S.O's. For Specific Customer's QA Specs.

A 4 3 2 2 Review Production & Test Instruct. For Compliance To Specs.

A 4 3 2 2 1 Review Assembly Instructions

A 4 3 2 2 2 Review Manufacturing Instructions

A 4 3 2 2 3 Review Test Instructions

A4323 Support Problem Investigations

A433 ASSURE OVERALL PRODUCT QUALITY
A4331 Perform Calibration
A43311 Calibrate Tooling & Gages
A43312 Calibrate Test Cells
A43313 Calibrate Electrical Test Equipment

A4332 Maintain Records
A4333 Support MRB

A434 AUDIT PRODUCT & SYSTEM QUALITY
A4341 Perform Product Audits Of Power Systems With Customer
A4342 Perform Random Product Audits
A4343 Audit Internal System & Procedures

A44 Provide Tooling (Production, Development, ILS)
A441 Produce, Coordinate & Monitor Tool Design & Tool Fab Orders
A442 Design Tool (Outside Sources)
A443 Fabricate Tools (Outside Sources)
A444 Maintain Tool (Jigs/Fix, Etc.)
A4441 Write & Issue Tool Repair Orders
A4442 Move Tools To Repair Shop & Return Tools To Production
A4443 Repair Tools (Outside Vendors)

A45 Control Material
A451 PROCURE MATERIAL
A4511 Establish Suppliers
A45111 Determine Potential Vendors
A45112 Request Vendor Qualification
A45113 Verify Qualifications & Place On Approved List

A4512 Write/Issue Purchase Orders
A45121 Receive Requisition & Drawing
A451211 Review Dwg. Package for latest Rev.
A451212 Obtain Engr. Specs., Etc.
A451213 Develop Lot Buy vs. Immediate Need

A45122 Prepare & Send RFQ
A45123 Receive & Evaluate Responses to RFQ
A451231 Perform Cost/Price Analysis
A451232 Evaluate Delivery Schedules
A451233 Check Supplier Is On Approved List

A4513 Maintain/Monitor P.O. and Delivery Schedule
A45131 Issue Engineering Changes To Supplier
A45132 Expedite Late Deliverables
A45133 Create & Issue P.O. Revisions

A452 RECEIVE MATERIAL
A4521 Verify Packing Ship quantity
A4522 Generate Receiver Ticket
A45221 Input Data Into CINCOM System
A45222 Send Receiver Ticket/Packing Slip to Matl Mover
A45223 Revise CINCOM Status From Dock To Stock

A4523 Move Production Parts To Receiving Inspection
A4524 Move Office Supplies/Non Production Parts

A453 STORE & ISSUE PARTS
A454 MAINTAIN & CONTROL MATERIAL DOCUMENTATION
A4541 Record Material Transactions In Computer
A4542 Analyze Physical Inventory
A4543 Reconcile & Close Work Orders
A45431 Receive completed Work Order Document
A45432 Analyze & Reconcile Work Order Variance
A45433 Refer Variance To Production Control
A45434 Close work Order/Update Computer

A455 HANDLE MATERIAL BETWEEM PLANTS & DEPARTMENTS

A456 PACKAGE & SHIP PRODUCT

A46 Produce Product
A461 FABRICATE COMPONENTS
A4611 Assemble Sheet Metal Products
A46111 Assemble Sheet Metal Components
A461111 Assemble Into Fixtures
A461112 Trim & Drill Assembly
A461113 Pressure Test/Flow Test Assembly
A461114 Expand Sheet Metal Assemblies
A462215 Check & Adjust Assy's To Qual Reqm'ts

A46112 Weld Sheet Metal Details
A461121 Spot Tack Assemblies
A461122 Roll Weld Assemblies
A461123 Fusion Weld Assemblies
A461124 Laser Weld Assemblies

A46113 Braze Sheet Metal Details
A46114 Inspect Sheet Metal
A461141 Measure Dimensions, Verify To Reqm'ts
A461142 Perform In-Process Inspection
A461143 Perform Nondestructive Testing
A4611431 Conduct Dye Penetrant Inspec
A4611432 Conduct Mag. Particle Inspec
A4611433 Conduct Eddie Current Inspec

A46115 Move & Store Material Within Department
A461151 Store Material In Current Dept
A461152 Store Fixtures & Tools
A461153 Store & Inventory Perishable Tools

A46116 Maintain Equipment Within Department
A4612 Manufacture Machine components
A4613 Overhaul Sheet Metal & Machine Components
A462 ASSEMBLE PRODUCT
A463 TEST PRODUCT
A464 PREPARE PRODUCTION FOR OVERHAUL
A465 PREFORM OUTSIDE VENDOR PROCESSING

A 5 SUPPORT PRODUCT

- A 5 1 Prod Technical Publications
- A 5 2 Provide Technical Training
- A 5 3 Depot Support Provisioning Requirements
- A54 Provide Techfld Support, FRACAS
  - A541 DET SUPT PROVISNG RQMTS
  - A542 ASES LKLY CAUSES OF PROB
  - A543 EVAL ADEQCY CUST INSTLIN
    - A5431 Travel to Customer
    - A5432 Visual Exam APU/Instl Intrf
    - A5433Review Stack-up Tolerances
  - A544 ANSWER TECHNICAL QUESTIONS
  - A545 DEV RESL & IMP RECMD CHG
- A 5 5 Provide Product Services
  - A 5 5 1 PROV PRODUCT SERVICES PLNG
    - A5511 Co-Or Review Of Contracts
    - A5512 Provide Business Perfmnd Report
    - A5513 Budget For Warranty Repair/Replace
    - A5514 Monitor Department Procedures
    - A5515 Provide I/P To Inventory Plan
  - A 5 5 2 SUPPORT BUSINESS DEVELOPMENT
    - A5521 Support After Sales Promo.
    - A5522 Provide Input Into Sales Forecast
    - A5523 Provide Repair Center Interface
    - A5524 Administer Third Party Support
    - A5525 Coordinate Product Support Agrmnts.
  - A 5 5 3 PROVIDE INTRM CONTRACT SUPPORT
  - A554 PROVIDE REPAIR SERVICES
    - A5541 Disposistion Product For Repair
    - A5542 Book & Bill Repair Order
      - A55421 Prepare & Issue Repair Orders
      - A55422 Prepare Cost Estimate To Repair
      - A55423 Prepare Final Cost Of Repair
    - A5543 Repair APU's In Field
    - A5544 Repair Fuel Controls In Field
    - A5545 Repair Electronic's In Field
  - A 5 5 5 PROVIDE PARTS SERVICE
    - A5551 Provide Parts Info Services
    - A5552 Administrate Parts Sales
    - A5553 Maintain Commercial Price Lists
    - A5554 Prepare Parts Proposals
- A56 Plan & Support Return/Phase-Out
- A 5 7 Perform Integrated Logistics Support
  - A 5 7 1 PERFORM LOGISTICS SUPPORT ANALYSIS (LSA)
    - A5711 Prepare LSA Record (LSAR)
      - A57111 LSA-015 Sequential Task Description
      - A57112 LAS-060 LSA Control Number Master File
      - A57113 LSA-061 Parts Master File
  - A 5 7 2 PERFORM LIFE CYCLE COST
  - A573 PERFORM DESIGN TO COSTS
  - A 5 7 4 PROVIDE RELIABILITY SUPPORT
    - A5741 Perform Failure Modes Effects & Critical Analysis (FMECA)
    - A5742 Perform Reliability Predictions
    - A5743 Perform Reliability Modeling

A5744 Establish Reliability Apportionment
A5745 Preform Failure Report, Anal & Corr Action System (FRACAS)
A5746 Provide Supplier & Subcontractor Rel Control
A5747 Provide Reliability Test Planning & Reporting
A5748 Perform Reliability Design Analysis
A5749 Provide Critical Items Control
A575 PERFORM MAINTAINABILITY
A5751 Perform Maintainability Predictions
A5752 Perform Human Factors Engineering
A5753 Perform Safety Hazard Analysis
A576 PROVIDE EQUIPMENT SUPPORT
A5761 Prepare Support Equipment Recommendation Data (SERD)
A5762 Provide Support Equipment Hardware
A577 PERFORM PROVISIONING
A5771 Prepare LSR & Data Records
A578 PROVIDE PUBLICATIONS SUPPORT
A5781 Prepare IPR
A5782 Prepare IPC
A5783 Prepare RPSTL
A5784 Provide Maintenance Support
57841 Perform Corrective Maintenance
57842 Perform Preventative Maintenance

# APPENDIX B

SUNDSTRAND POWER SYSTEMS

MASTER COST CENTER LIST
ALL COST CENTERS SELECTED

**DATA FOR JANUARY 1, 1990 THRU JUNE 30, 1990**
**"AS IS"**

COST CENTER: 006 OPERATIONS ADMINISTRATION HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 475.097 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 291.188 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 89.564 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 316 | |
| MATL | MATERIALS | E | V | 866 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 675 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 38.040 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 40 | |
| UTILTY | UTILITIES | A | SV | 7.017 | |
| MISC | MISC | A | V | 3.607 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 4.134 | |
| | | | Total Assigned Cost: | 910.544 | |

COST CENTER: 007 MANUFACTURING ADMINISTRATI HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 297.319 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 531 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 94 | |
| TOOLS | TOOLING | A | V | 125 | |
| FACIL | FACILITIES | A | V | 12 | |
| UTILTY | UTILITIES | A | SV | 1.016 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 1.308 | |
| | | | Total Assigned Cost: | 300.405 | |

MASTER COST CENTER LIST ALL COST CENTERS SELECTED

## APPENDIX B

SUNDSTRAND POWER SYSTEMS — MASTER COST CENTER LIST
ALL COST CENTERS SELECTED

COST CENTER: 009 QUALITY CONTROL HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 109.767 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 37.789 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 56.836 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 11.628 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 32 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 257 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 46 | |
| EQUIP | EQUIPMENT | A | V | 6.868 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 602 | |
| MISC | MISC | A | V | 22 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 4.223 | |
| | | | Total Assigned Cost: | 228.072 | |

COST CENTER: 010 PROCUREMENT QUALITY ASSURA HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 463.110 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 341.860 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 753 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 5.975 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 5.386 | |
| MISC | MISC | A | V | 7.317 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 40.368 | |
| | | | Total Assigned Cost: | 864.769 | |

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COST CENTER: 011 QUALITY ASSURANCE HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 238.992 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 39.255 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 7.205 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 2.212 | |
| EQUIP | EQUIPMENT | A | V | 4.484 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 3.694 | |
| MISC | MISC | A | V | 4.683 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 11.917 | |
| | Total Assigned Cost: | | | 312.442 | |

COST CENTER: 012A QAULITY SYSTEMS ADMIN HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 145.467 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 5.442 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 182 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | Total Assigned Cost: | | | 151.091 | |

COST CENTER: 013 COMBUSTER ASSEMBLY HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 325.571 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 6.213 | |
| OUTSER | OUTSIDE SERVICES | A | V | 14.118 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 33.641 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 85.679 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 141 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 139.987 | |
| TOOLS | TOOLING | A | V | 87.824 | |
| FACIL | FACILITIES | A | V | 7.648 | |
| UTILTY | UTILITIES | A | SV | 170 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 105 | |
| | | | Total Assigned Cost: | 701.097 | |

COST CENTER: 014 FACILITIES ADMIN HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 117.721 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 38.540 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 63.914 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 63 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 29.645 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 61.053 | |
| UTILTY | UTILITIES | A | SV | 348 | |
| MISC | MISC | A | V | 4.513 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 1.065 | |
| | | | Total Assigned Cost: | 316.862 | |

COST CENTER: 015 PRODUCTION TEST HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 163.182 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 18.426 | |
| OUTSER | OUTSIDE SERVICES | A | V | 10.189 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 254.108 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 7 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 91.754 | |
| TOOLS | TOOLING | A | V | 5.250 | |
| FACIL | FACILITIES | A | V | 3.192 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | | | Total Assigned Cost: | 546.108 | |

COST CENTER: 016 FUEL CONTROL ASSEMBLY HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 90.255 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 955 | |
| OUTSER | OUTSIDE SERVICES | A | V | 1.118 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 13.181 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 6.631 | |
| TOOLS | TOOLING | A | V | 188 | |
| FACIL | FACILITIES | A | V | 88 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | | | Total Assigned Cost: | 112.416 | |

COST CENTER: 018 TRAFFIC/SHIPPING/RECEIVING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 504.877 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 6.918 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 801 | |
| MATL | MATERIALS | E | V | 2.622 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 1.728 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 6.804 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 423 | |
| MISC | MISC | A | V | 5.793 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | Total Assigned Cost: | | | 531.966 | |

COST CENTER: 019 PLANT ENGRG/MAINTENANCE HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 333.840 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 18.573 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 13.202 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 17.631 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 2.840 | |
| UTILTY | UTILITIES | A | SV | 883 | |
| MISC | MISC | A | V | 88 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | Total Assigned Cost: | | | 387.057 | |

COST CENTER: 020 OPERATIONS ADMIN HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 18.560 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 224.392 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 914 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 5.509 | |
| OUTINF | OUTSIDE INFO SYS | . | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 4.920 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 794 | |
| MISC | MISC | A | V | 2.135 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 12.599 | |
| | | | Total Assigned Cost: | 269.823 | |

COST CENTER: 021 PURCHASING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 669.800 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 56.995 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 732 | |
| MATL | MATERIALS | E | V | 26.211 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 4.595 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 109.898 | |
| TOOLS | TOOLING | A | V | 26.211 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 18.116 | |
| MISC | MISC | A | V | 7.575 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 33.336 | |
| | | | Total Assigned Cost: | 953.469 | |

COST CENTER: 022 MATERIAL MANAGEMENT HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 374.337 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 5.683 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 14.708 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 1.773 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 2.127 | |
| | Total Assigned Cost: | | | 398.628 | |

COST CENTER: 023 PRODUCTION & INVENTORY CON HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 336.497 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 3.694 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 1.053 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 2.623 | |
| EQUIP | EQUIPMENT | A | V | 4.798 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 1.976 | |
| MISC | MISC | A | V | 7.025 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 3.793 | |
| | Total Assigned Cost: | | | 361.459 | |

COST CENTER: 025 DEVELOPMENT ASSEMBLY HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 320,410 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 2,177 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 1,358 | |
| SCRAP | SCRAP | A | V | 30,024 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 6,306 | |
| TOOLS | TOOLING | A | V | 2,115 | |
| FACIL | FACILITIES | A | V | 288 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | Total Assigned Cost: | | | 362,678 | |

COST CENTER: 026 MANUFACTURING ENGINEERING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 1,122,020 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 54,707 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 473,306 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 15,380 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 1,489 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 1,481 | |
| TOOLS | TOOLING | A | V | 7,061 | |
| FACIL | FACILITIES | A | V | 3,359 | |
| UTI'TY | UTILITIES | A | SV | 9,884 | |
| MISC | MISC | A | V | 4,666 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 45,056 | |
| | Total Assigned Cost: | | | 1,738,409 | |

COST CENTER: 027 PRODUCTION ASSEMBLY HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 606.541 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 13.009 | |
| OUTSER | OUTSIDE SERVICES | A | V | 3.919 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 50.041 | |
| SCRAP | SCRAP | A | V | 179,414 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 4.139 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 32.582 | |
| TOOLS | TOOLING | A | V | 37,459 | |
| FACIL | FACILITIES | A | V | 172 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 70 | |
| | Total Assigned Cost: | | | 927.346 | |

COST CENTER: 028 QUALITY CONTROL INSPECTION HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 1.034.981 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 8.815 | |
| OUTSER | OUTSIDE SERVICES | A | V | 1.335 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 4.927 | |
| SCRAP | SCRAP | A | V | 121,562 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 116.988 | |
| TOOLS | TOOLING | A | V | 1.251 | |
| FACIL | FACILITIES | A | V | 1.162 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 341 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 202 | |
| | Total Assigned Cost: | | | 1.291.564 | |

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COST CENTER: 029 rUFFIN OCCUPANCY HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 1.907 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 97 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 259 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 342.440 | |
| TOOLS | TOOLING | A | V | 89 | |
| FACIL | FACILITIES | A | V | 196.374 | |
| UTILTY | UTILITIES | A | SV | 239,089 | |
| MISC | MISC | A | V | 239.494 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 218.430 | |
| | | | Total Assigned Cost: | 1.238.179 | |

COST CENTER: 078 IMPELLER CELL HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 436.983 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 3.505 | |
| OUTSER | OUTSIDE SERVICES | A | V | 351 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 48.332 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 7.500 | |
| EQUIP | EQUIPMENT | A | V | 399.897 | |
| TOOLS | TOOLING | A | V | 27.641 | |
| FACIL | FACILITIES | A | V | 1,620 | |
| UTILTY | UTILITIES | A | SV | 106 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | | | Total Assigned Cost: | 925.935 | |

COST CENTER: 258 ADVANCED TECHNOLOGY ENGR HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 56.605 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 3.166 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 6.744 | |
| | | | Total Assigned Cost: | 66.515 | |

COST CENTER: 259 TECHNONLGY DEVELOPMENT4 HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 215.020 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 362 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 562 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 1.595 | |
| MISC | MISC | A | V | 1,425 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 7.119 | |
| | | | Total Assigned Cost: | 226.083 | |

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COST CENTER: 260 ENGINEERING ADMINISTRATION HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 129,362 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 24,183 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 17,511 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 1,962 | |
| EQUIP | EQUIPMENT | A | V | 31,718 | |
| TOOLS | TOOLING | A | V | 1,031 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 3,294 | |
| MISC | MISC | A | V | 4,192 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 43,591 | |
| | Total Assigned Cost: | | | 256,844 | |

COST CENTER: 261 AEROTHERMAL ENGINEERING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 245,367 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 1,020 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 12 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 981 | |
| UTILTY | UTILITIES | A | SV | 1,860 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 7,302 | |
| | Total Assigned Cost: | | | 256,542 | |

COST CENTER: 262 MECHANICAL DESIGN & ANALYS HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 406,397 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 275,783 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 654 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 508 | |
| TOOLS | TOOLING | A | V | 148 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 3,317 | |
| MISC | MISC | A | V | 1,200 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 15,593 | |
| | Total Assigned Cost: | | | 703,600 | |

COST CENTER: 263 DEVELOPMENT TEST ENGINEERI HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 858,331 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 813 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 209,088 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 89 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 2,121 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 210,888 | |
| TOOLS | TOOLING | A | V | 17 | |
| FACIL | FACILITIES | A | V | 45,557 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 1,155 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | Total Assigned Cost: | | | 1,328,059 | |

COST CENTER: 264 MATERIALS AND PROCESSES HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 222.547 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 3.391 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 676 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 16.256 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 3.242 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 22.678 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 1.221 | |
| MISC | MISC | A | V | 835 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 6.799 | |
| | Total Assigned Cost: | | | 277.645 | |

COST CENTER: 266 SYSTEMS & CONTROLS ENGINEE HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 9.986 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 31.385 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 216 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 150 | |
| MATL | MATERIALS | E | V | 72 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 4.590 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 35.086 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 3.372 | |
| MISC | MISC | A | V | 2.414 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 9.626 | |
| | Total Assigned Cost: | | | 96.897 | |

COST CENTER: 267 MECHANICAL DRAFTING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 213,554 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 182,963 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 517,240 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 306 | |
| MATL | MATERIALS | E | V | 2,244 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 2,691 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 5,720 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 1,358 | |
| MISC | MISC | A | V | 108 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 9,333 | |
| | Total Assigned Cost: | | | 935,517 | |

COST CENTER: 268 COMMERCIAL PROJECTS HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 522,696 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 464,529 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 2,306 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 2,288 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 8,550 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 5,497 | |
| MISC | MISC | A | V | 1,175 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 10,531 | |
| | Total Assigned Cost: | | | 1,017,572 | |

COST CENTER: 270    PROGRAM MANAGEMENT    HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 934,002 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 272,052 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 2,008 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 2,784 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 966 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 8,295 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 10,953 | |
| MISC | MISC | A | V | 11,252 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 70,893 | |
| | Total Assigned Cost: | | | 1,313,205 | |

COST CENTER: 271    QUALITY ENGINEERING    HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 146,520 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 9,162 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 285,975 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 12 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 2,509 | |
| MISC | MISC | A | V | 18,884 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 5,986 | |
| | Total Assigned Cost: | | | 469,048 | |

COST CENTER: 273 I.L.S. ENGINEERING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 736.044 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 63.788 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 261 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 16.129 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 2.738 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 65 | |
| EQUIP | EQUIPMENT | A | V | 22.884 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 4.332 | |
| MISC | MISC | A | V | 1.876 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | | | Total Assigned Cost: | 848,117 | |

COST CENTER: 274 I.L.S. SUPPORT SYSTEMS HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 302.023 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 41,895 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 21.565 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 5,660 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 5,632 | |
| EQUIP | EQUIPMENT | A | V | 21,138 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 3.843 | |
| MISC | MISC | A | V | 177 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 5.817 | |
| | | | Total Assigned Cost: | 407.750 | |

COST CENTER: 275 ILS PROJECT ENGINEERING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 21,419 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 101 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 2,867 | |
| MISC | MISC | A | V | 21,666 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 2,658 | |
| | Total Assigned Cost: | | | 48,711 | |

COST CENTER: 278A T46/47 SERVICE ENGINEERING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 272,111 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 126 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 1,465 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 54 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 6,439 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 7,572 | |
| MISC | MISC | A | V | 901 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 1,837 | |
| | Total Assigned Cost: | | | 290,505 | |

COST CENTER: 279A GPS & T40 SERVICE ENGINEER HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 311.597 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 1.528 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 261 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 316 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 16.381 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 7.764 | |
| MISC | MISC | A | V | 2.629 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 47.835 | |
| | Total Assigned Cost: | | | 388.311 | |

COST CENTER: 391 ADMIN SERVICES HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 108.737 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 0 | |
| REWORK | REWORK LBR | A | V | 106,516 | |
| OUTSER | OUTSIDE SERVICES | A | V | 1.087 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 82,697 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 141,900 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 18,771 | |
| MISC | MISC | A | V | 9,242 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 2.102 | |
| | Total Assigned Cost: | | | 471.052 | |

COST CENTER: 392 FINANCE & ADMINISTRATION HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 107,001 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 50 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 709 | |
| MISC | MISC | A | V | 475 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 553 | |
| | Total Assigned Cost: | | | 108,788 | |

COST CENTER: 789 PROV & INV PLANNING HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 40,076 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 0 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 3,207 | |
| | Total Assigned Cost: | | | 43,283 | |

COST CENTER: 790 PRODUCT SUPPORT ADMINISTRA HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 326.725 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 39 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 2.360 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 2.694 | |
| TOOLS | TOOLING | A | V | 732 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 5.627 | |
| MISC | MISC | A | V | 5,148 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 54.375 | |
| | | | Total Assigned Cost: | 397.700 | |

COST CENTER: 792 SUPPORT ADMINISTRATION HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 519.221 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 48.385 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 5.669 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 5.558 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 16,132 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 8.919 | |
| MISC | MISC | A | V | 5.771 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 48.446 | |
| | | | Total Assigned Cost: | 658,101 | |

COST CENTER: 793A COMMERCIAL/INTERNTL MARKET HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 367,906 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 141 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 590 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 1,293 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 7,549 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 7,270 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 80,704 | |
| | Total Assigned Cost: | | | 465,453 | |

COST CENTER: 795 REPAIR ADMINISTRATION HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 31,515 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 5 | |
| MISC | MISC | A | V | 0 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | Total Assigned Cost: | | | 31,520 | |

COST CENTER: 796 MARKETING SERVICES HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 99,704 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 61,131 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 130 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 10,154 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 332 | |
| MISC | MISC | A | V | 34,729 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 2,387 | |
| | | | Total Assigned Cost: | 208,567 | |

COST CENTER: 797 FIELD SERVICE HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 43,243 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 94 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 146 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 242 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 219 | |
| MISC | MISC | A | V | 260 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 0 | |
| | | | Total Assigned Cost: | 44,204 | |

COST CENTER: 933 HUMAN RESOURCES HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 278,855 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 52,041 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 42 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 2,277 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 3,079 | |
| TOOLS | TOOLING | A | V | 45 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 11,157 | |
| MISC | MISC | A | V | 142,585 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 8,175 | |
| | Total Assigned Cost: | | | 498,256 | |

COST CENTER: 939A FINANCIAL HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 747,461 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 1,356 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 14,855 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 8,056 | |
| MISC | MISC | A | V | 97,738 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 10,872 | |
| | Total Assigned Cost: | | | 880,338 | |

COST CENTER: 941A INFO RESOURCE MNGMN HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 326,142 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 75,022 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 1,572 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 31,897 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 49,907 | |
| EQUIP | EQUIPMENT | A | V | 41,786 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 76,473 | |
| MISC | MISC | A | V | 217 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 3,720 | |
| | Total Assigned Cost: | | | 606,736 | |

COST CENTER: 969A CONTRACTS-COMMERCIAL HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 270,056 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 2,745 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 569 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 2,793 | |
| MISC | MISC | A | V | 7,562 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 29,272 | |
| | Total Assigned Cost: | | | 312,997 | |

COST CENTER: 970A PROGRAM MANAGEMENT HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 22,241 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 142,644 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 2,138 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 1,689 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 951 | |
| EQUIP | EQUIPMENT | A | V | 1,917 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 2,281 | |
| MISC | MISC | A | V | 155 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 8,292 | |
| | Total Assigned Cost: | | | 182,308 | |

COST CENTER: 971A COMMERCIAL CONTRACTS HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 73,339 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 0 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 0 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 0 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 0 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 0 | |
| UTILTY | UTILITIES | A | SV | 46 | |
| MISC | MISC | A | V | 1,700 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 7,872 | |
| | Total Assigned Cost: | | | 82,957 | |

COST CENTER: 985 SECURITY HIERARCHY CODE:

Cost Elements

| CODE | DESCRIPTION | STATUS | COST TYPE | AMOUNT | CODE |
|---|---|---|---|---|---|
| DIRLBR | DIRECT TOUCH LABOR | A | V | 0 | |
| IPRDLB | INDIRECT TOUCH LABOR | A | V | 0 | |
| DNPDLB | DIRECT NONTOUCH LBR | A | V | 0 | |
| INDLBR | INDIRECT NONTOUCH LBR | A | SV | 156,953 | |
| REWORK | REWORK LBR | A | V | 0 | |
| OUTSER | OUTSIDE SERVICES | A | V | 2,183 | |
| OUTMNT | OUTSD MAINT SERV & MAT'L | A | SV | 0 | |
| MATL | MATERIALS | E | V | 1,972 | |
| SCRAP | SCRAP | A | V | 0 | |
| ICC | INVENTORY CARRY'G COST | A | V | 0 | |
| SUPPLY | SUPPLIES & PERISH TOOLS | A | V | 3,780 | |
| OUTINF | OUTSIDE INFO SYS | A | SF | 0 | |
| EQUIP | EQUIPMENT | A | V | 8,651 | |
| TOOLS | TOOLING | A | V | 0 | |
| FACIL | FACILITIES | A | V | 1,943 | |
| UTILTY | UTILITIES | A | SV | 2,177 | |
| MISC | MISC | A | V | 9,213 | |
| TRA/ET | TRAVEL & ENTERTAINMENT | E | V | 1,751 | |
| | Total Assigned Cost: | | | 188,623 | |

# APPENDIX C

DISCOUNTED CASH FLOW MODEL

| | | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|
| | Year: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **SECTION I. CORE DATA** | | | | | | | | |
| 1 Contractor Investment | | 998.6 | 3,225.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 998.6 | 4,224.2 | 4,224.2 | 4,224.2 | 4,224.2 | 4,224.2 | 4,224.2 |
| 2 Contractor Expenses | | 0.0 | 16.5 | 16.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 16.5 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 |
| 3 DoD/Government Funding | | 1,671.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 1,671.0 | 1,671.0 | 1,671.0 | 1,671.0 | 1,671.0 | 1,671.0 | 1,671.0 |
| 4 Savings Available to DoD | | 0.0 | 0.0 | 1,359.8 | 1,105.2 | 1,001.9 | 908.5 | 791.8 |
| Cumulative Total | | 0.0 | 0.0 | 1,359.8 | 2,465.0 | 3,466.9 | 4,375.4 | 5,167.2 |
| **SECTION II. INCREMENTAL CASH FLOWS** | | | | | | | | |
| 5 Productivity Savings Reward | | 0.0 | 0.0 | 679.9 | 552.6 | 500.9 | 454.3 | 395.9 |
| Cumulative Total | | 0.0 | 0.0 | 679.9 | 1,232.5 | 1,733.4 | 2,187.7 | 2,583.6 |
| 6 Cost of Money (CAS 414) | 13.00% | 0.0 | 0.0 | 251.7 | 480.5 | 434.7 | 389.0 | 343.2 |
| 7 CAS 409 Depreciation | | 0.0 | 0.0 | 352.0 | 352.0 | 352.0 | 352.0 | 352.0 |
| 8 Profit Effect | | 0.0 | 0.0 | 825.2 | 732.3 | 806.9 | 887.9 | 958.0 |
| 9 Subtotal: DoD Cash Flows to Contractor | | 0.0 | 0.0 | 2,108.7 | 2,117.4 | 2,094.6 | 2,083.2 | 2,049.1 |
| 10 Salvage Value | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 Contractor Before-Tax Cash Flow | | (998.6) | (3,242.1) | 2,092.2 | 2,117.4 | 2,094.6 | 2,083.2 | 2,049.1 |
| **SECTION III. TAX CALCULATIONS** | | | | | | | | |
| 12 ACRS Depreciation | | 0.0 | 0.0 | 401.3 | 401.3 | 401.3 | 401.3 | 401.3 |
| 13 Contractor Taxable Income | | 0.0 | (16.5) | 1,691.0 | 1,716.1 | 1,693.3 | 1,681.9 | 1,647.8 |
| 14 Contractor Income Tax | 38% | 0.0 | 6.3 | (642.6) | (652.1) | (643.4) | (639.1) | (626.2) |
| 15 Investment Tax Credit | 10% | 0.0 | 0.0 | 422.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 Contractor After-Tax Cash Flow | | (998.6) | (3,235.8) | 1,872.1 | 1,465.3 | 1,451.1 | 1,444.0 | 1,422.9 |
| Cumulative Total | | (998.6) | (4,234.4) | (2,362.3) | (897.0) | 554.1 | 1,998.2 | 3,421.1 |
| **SECTION IV. SUMMARY** | | | | | | | | |
| 17 DoD Program Benefit (Without Incentive) | | (1,671.0) | 0.0 | 1,359.8 | 1,105.2 | 1,001.9 | 908.5 | 791.8 |
| Cumulative Total | $3,496.2 | (1,671.0) | (1,671.0) | (311.2) | 794.0 | 1,795.9 | 2,704.4 | 3,496.2 |
| 18 DoD Program Benefit (With Incentive) | | (1,671.0) | 0.0 | 679.9 | 552.6 | 500.9 | 454.3 | 395.9 |
| Cumulative Total | $912.6 | (1,671.0) | (1,671.0) | (991.1) | (438.5) | 62.4 | 516.7 | 912.6 |
| 19 DoD Payback Period | 4.9 years | | | | | | | |
| 20 DoD Rate of Return | 12.8% | | | | | | | |
| 21 Government Benefit | | (1,671.0) | (6.3) | 900.0 | 1,204.7 | 1,144.4 | 1,093.4 | 1,022.1 |
| Cumulative Total | | (1,671.0) | (1,677.3) | (777.2) | 427.5 | 1,571.9 | 2,665.3 | 3,687.3 |
| 22 Government Payback Period | 3.6 years | | | | | | | |
| 23 Government Rate of Return | 36.5% | | | | | | | |
| 24 Contractor Internal Rate of Return | | | | | | | | |
| Without Incentive | 12.5% | | | | | | | |
| With Incentive | 22.4% | | | | | | | |
| 25 Contractor Payback Period | 4.6 years | | | | | | | |

| MODEL INPUTS: Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|
| Contractor Investment | 998.6 | 3,225.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Contractor Expenses | 0.0 | 16.5 | 16.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| DoD/Government Funding | 1,671.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Savings Available to DoD | 0.0 | 0.0 | 1,359.8 | 1,105.2 | 1,001.9 | 908.5 | 791.8 |
| Productivity Savings Reward | 0.0 | 0.0 | 679.9 | 552.6 | 500.9 | 454.3 | 395.9 |
| Profit Effect | 0.0 | 0.0 | 825.2 | 732.3 | 806.9 | 887.9 | 958.0 |
| Salvage Value | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

CAS 414 Rate ................ 0.1300

CAS 409 Depreciation:

Depreciation Method ...... 1

(1:Straight Line: 2:Sum-of-Years: 3:Sum-of-Years/Half-Year; 4:150% Declining Balance: 5:150% DB. Switch to St Line)

Asset Service Life (years) 12

Year Placed into Service 3

ACRS Depreciation:

Depreciation Method ...... 2

(1:Standard ACRS Tables; 2:Straight Line)

Asset Class (Service Life) 10

(3: 3-yr; 5: 5-yr; 10: 10-yr)

Year Placed into Service 3

Contractor Tax Rate ......... 0.38

Investment Tax Credit Rate .. 0.10

Completed Contract - Tax Lag 0 years (0 implies no lag)

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